AUGUST, 1958

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VOL. 189 PART 4

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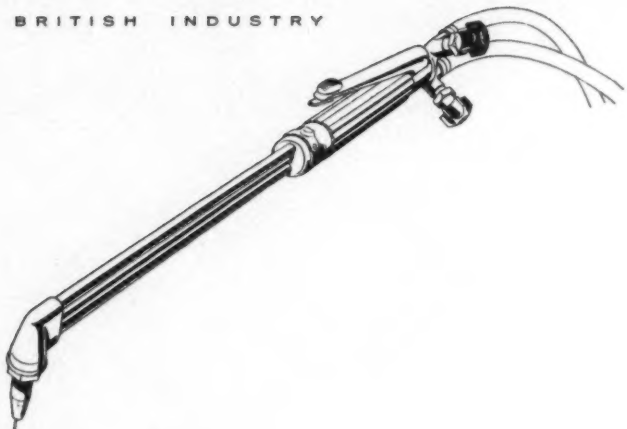

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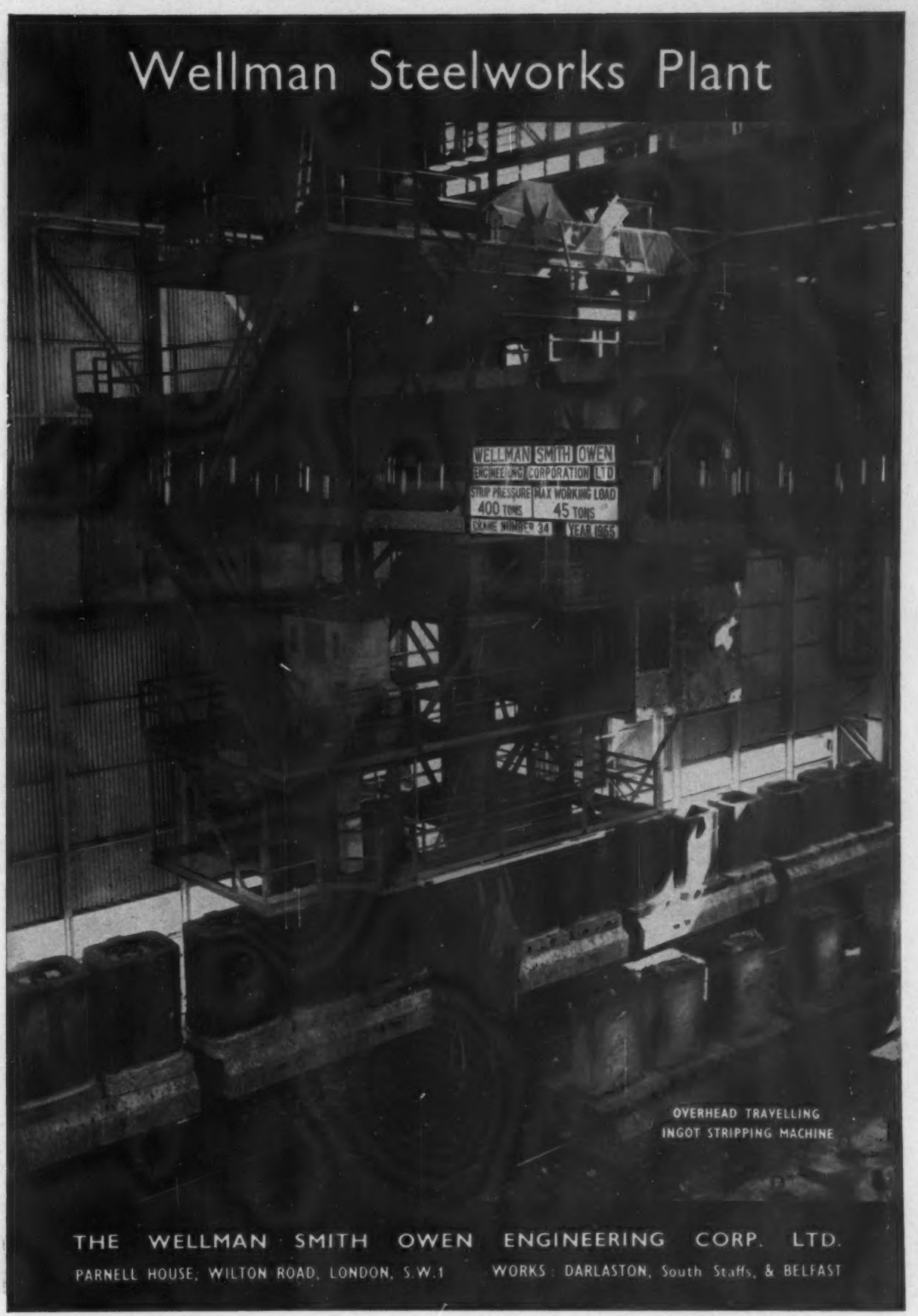

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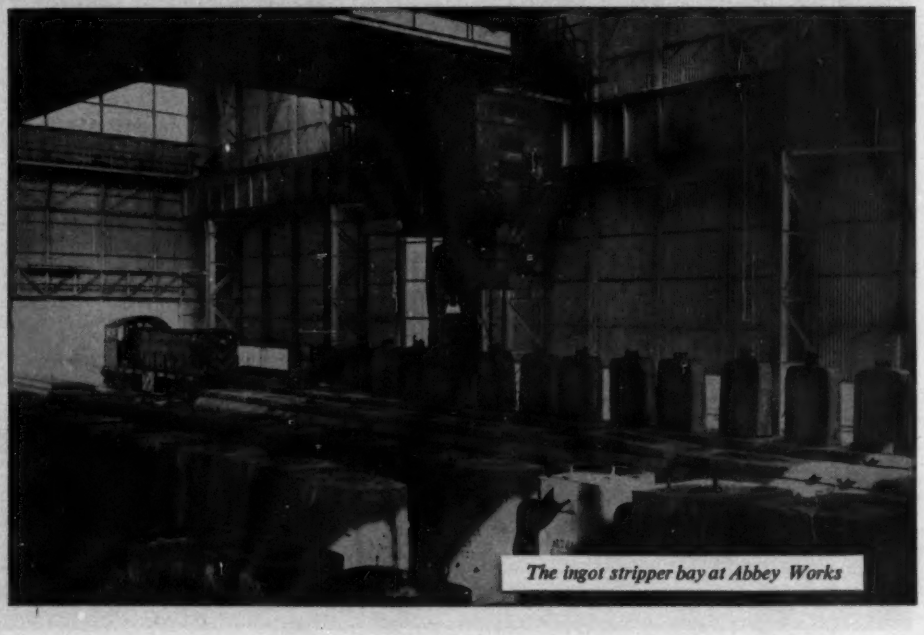

The ingot stripper bay at Abbey Works

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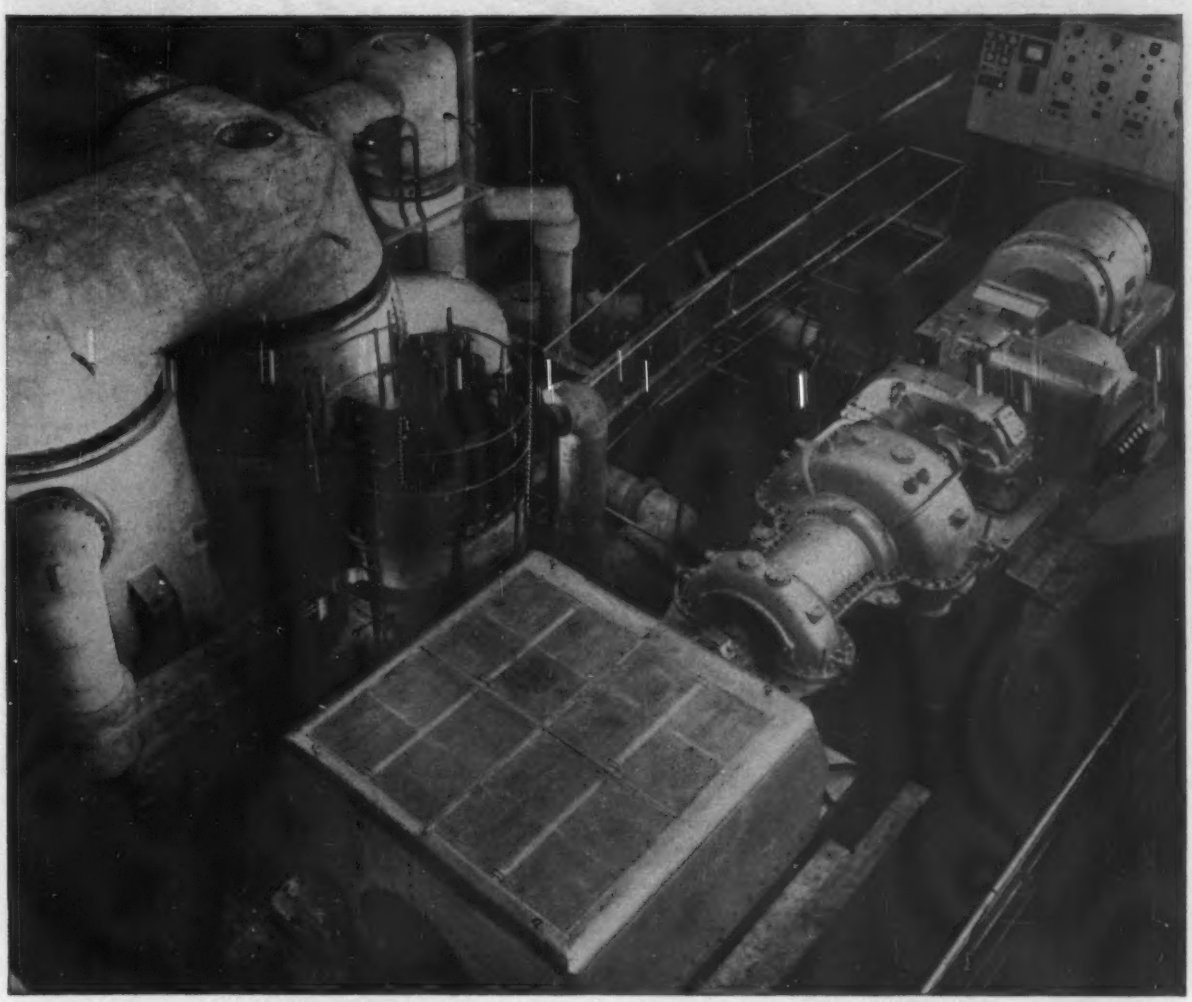

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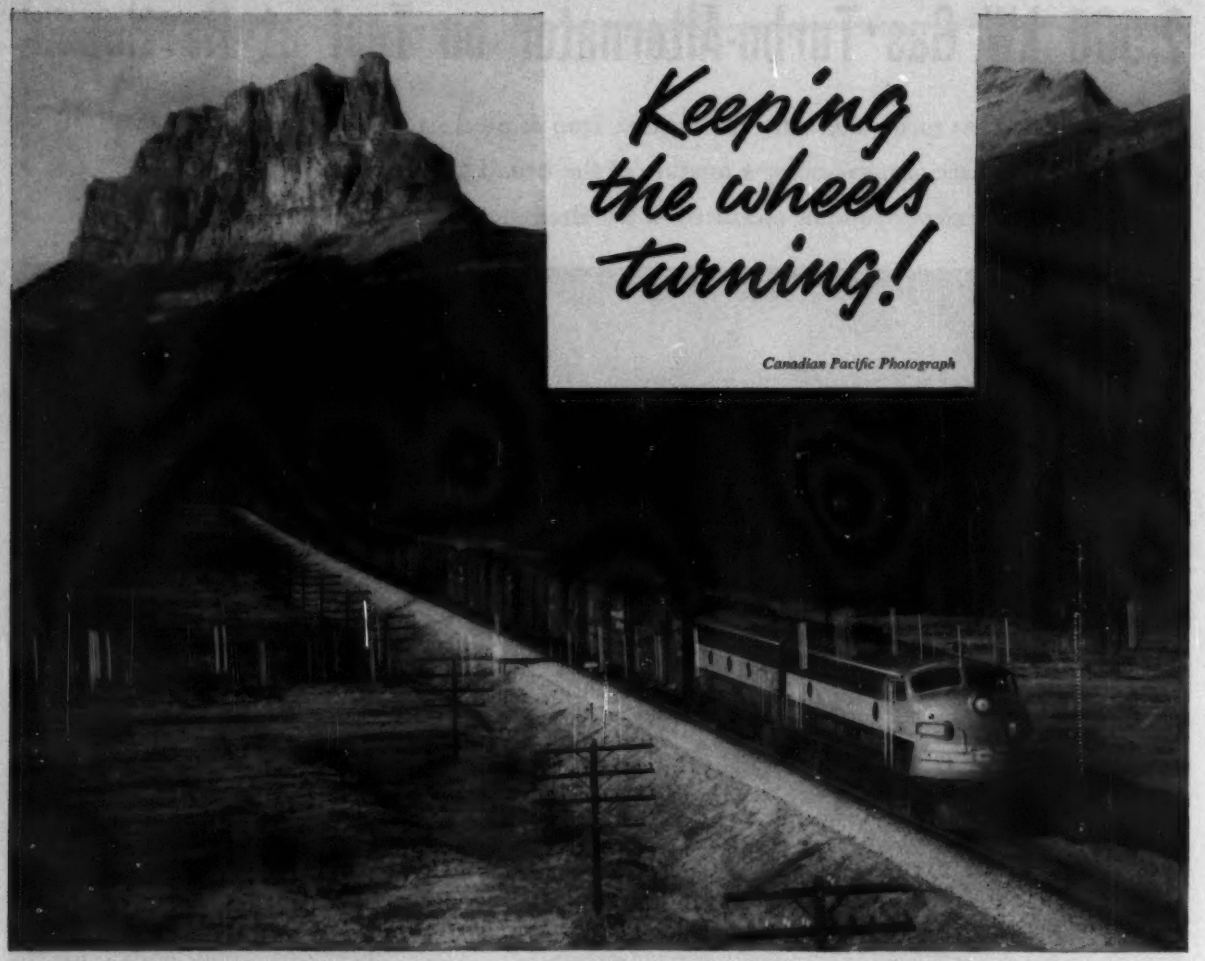

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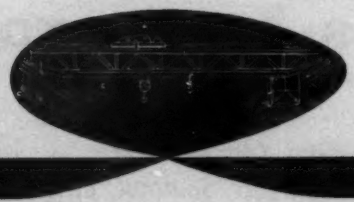

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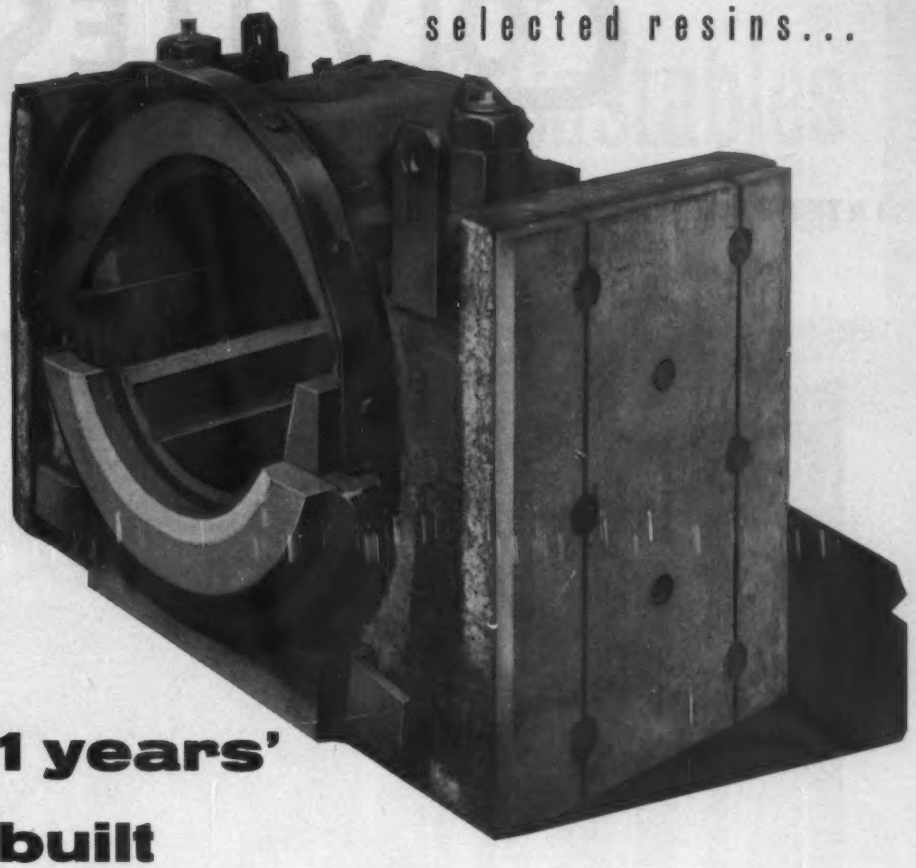

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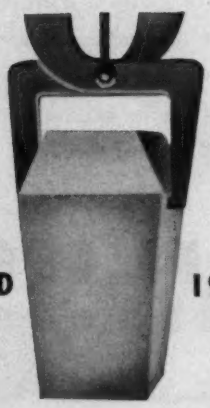

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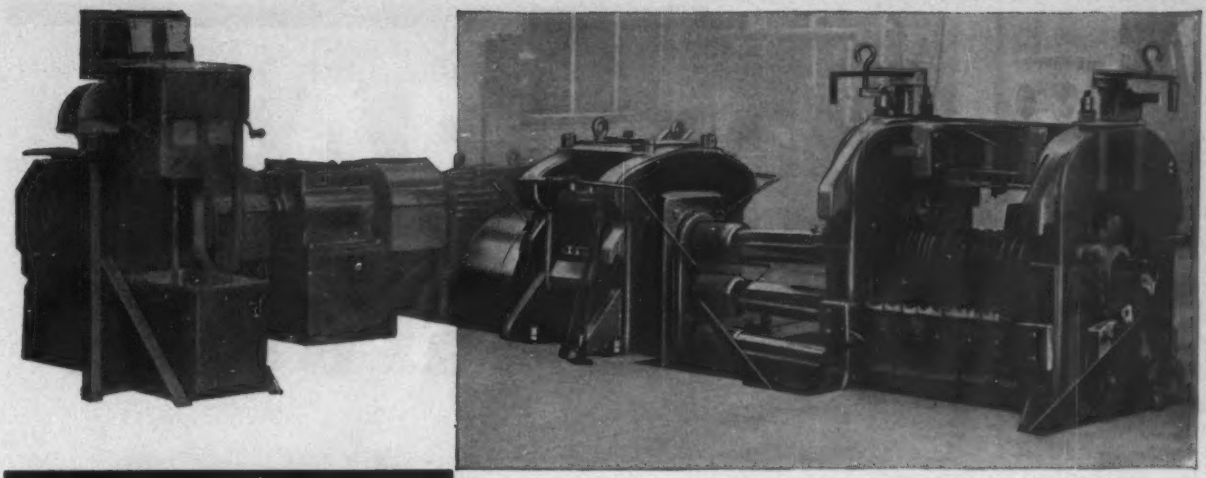

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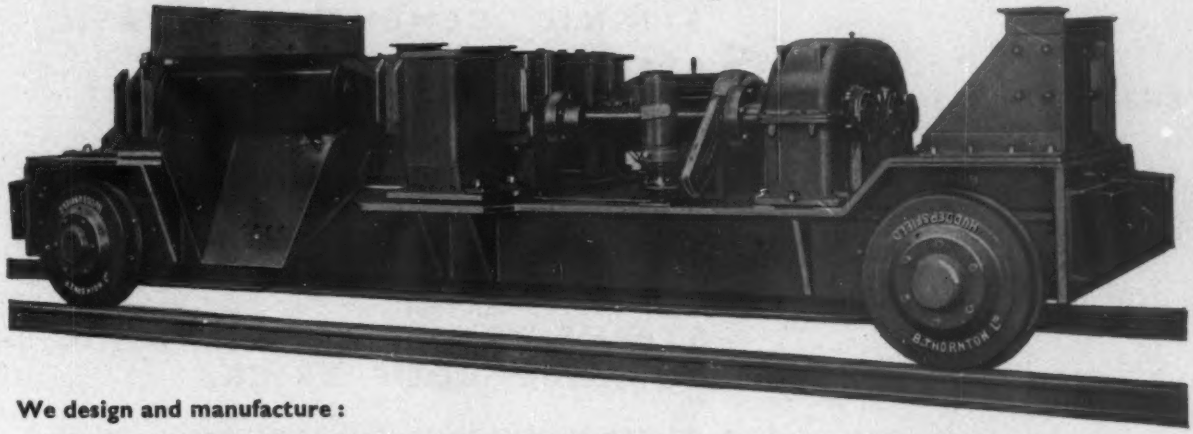

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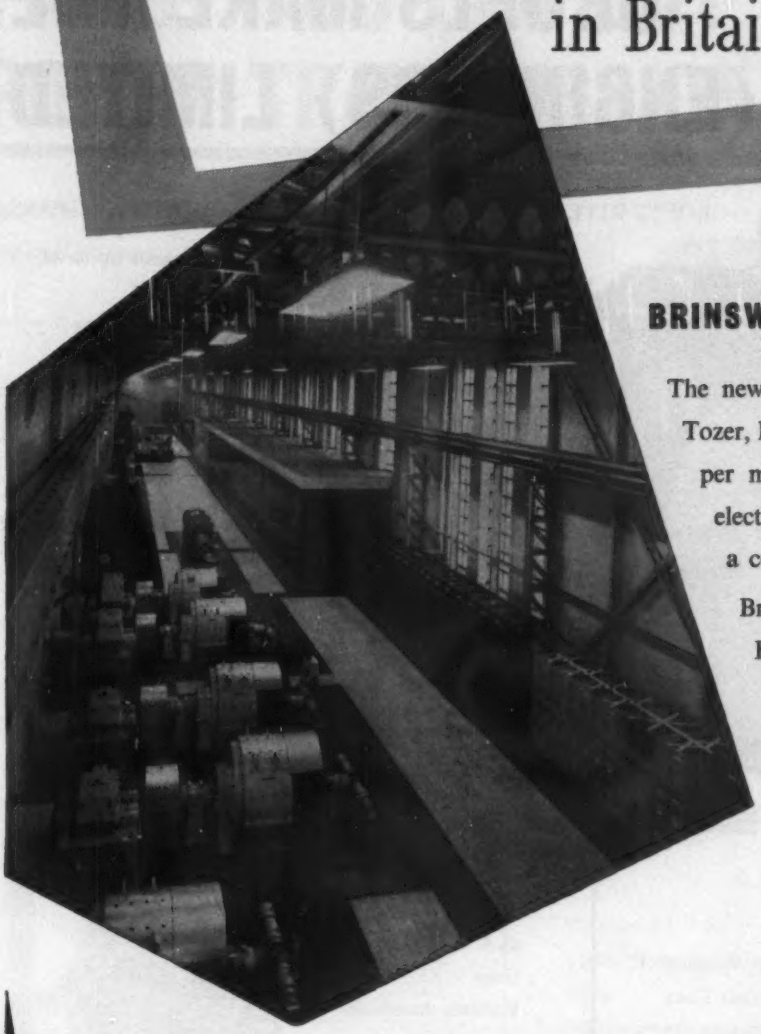

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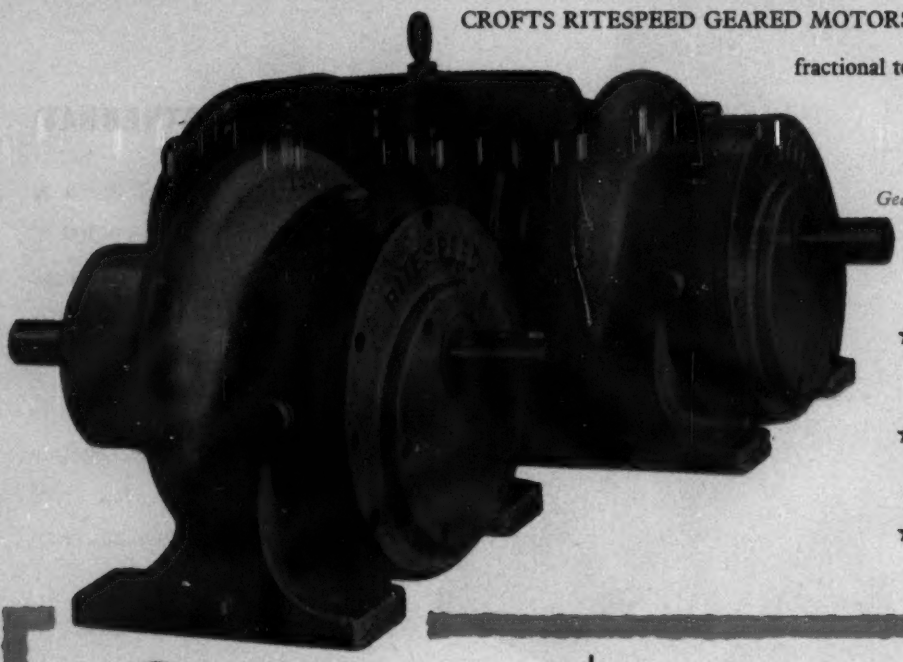

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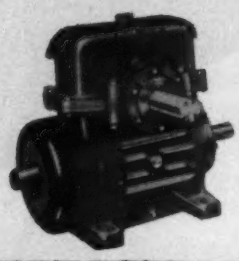

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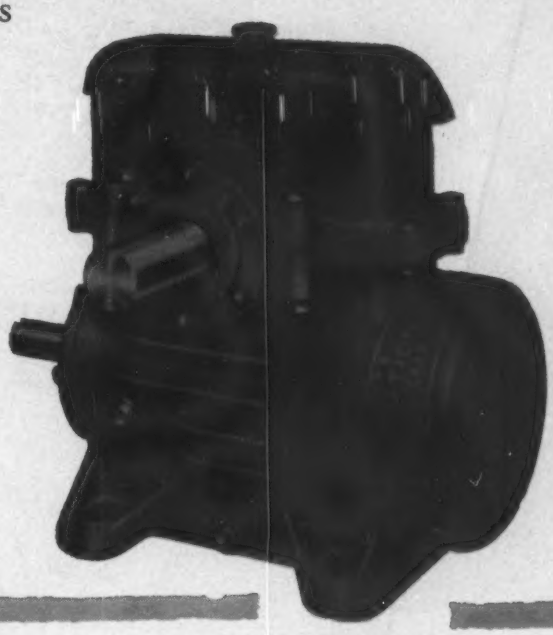

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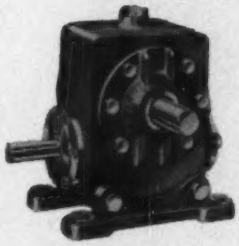

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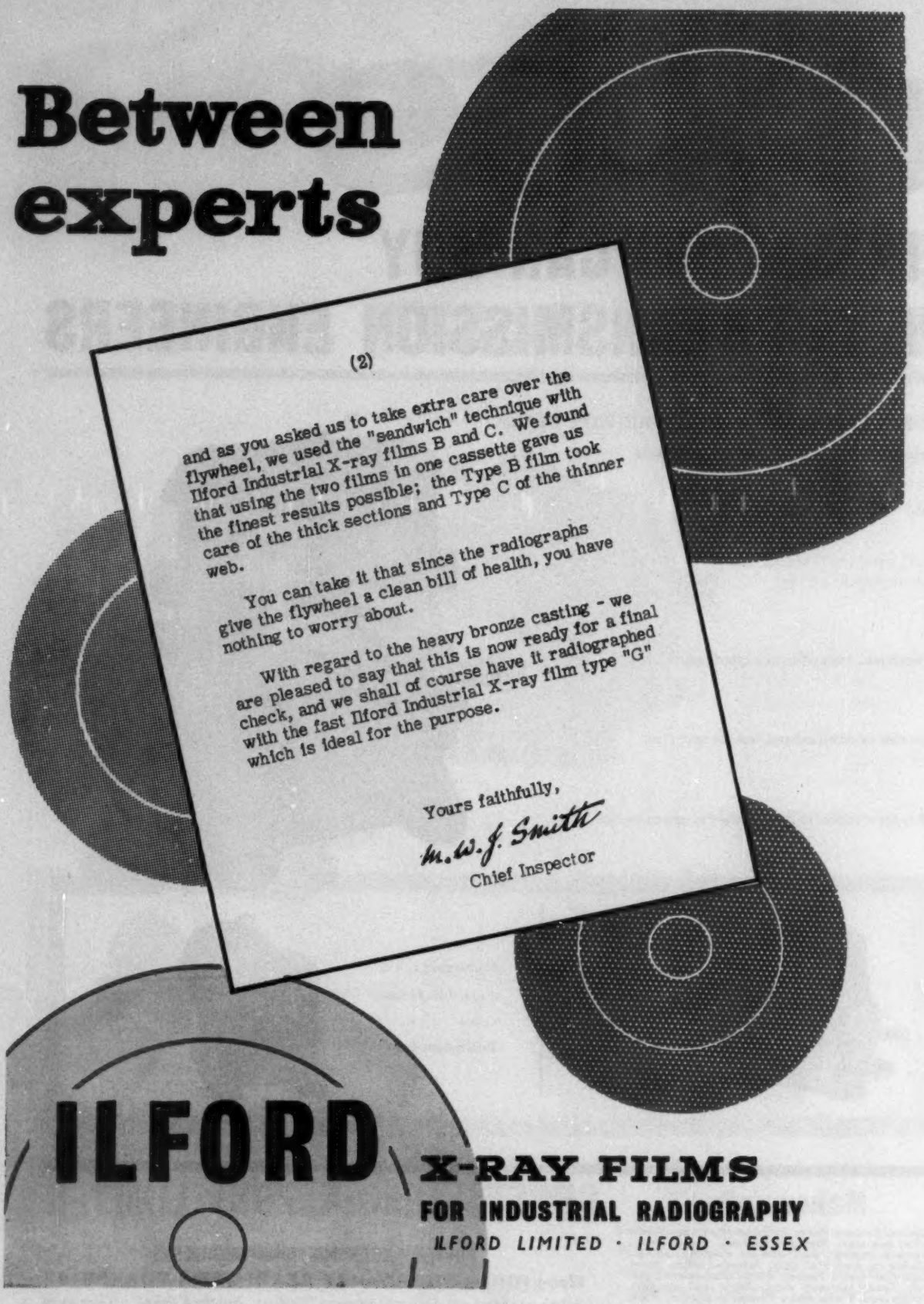
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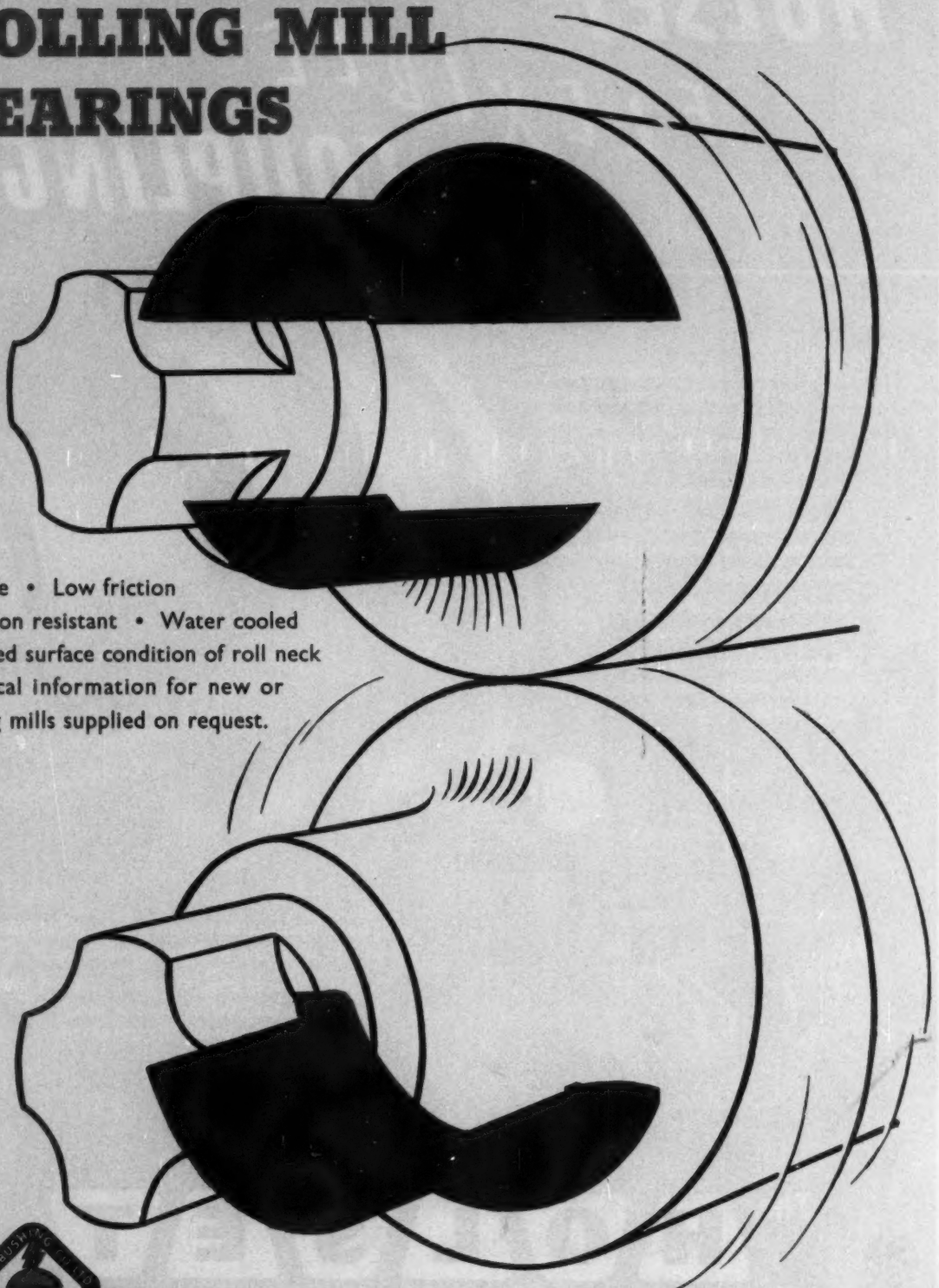

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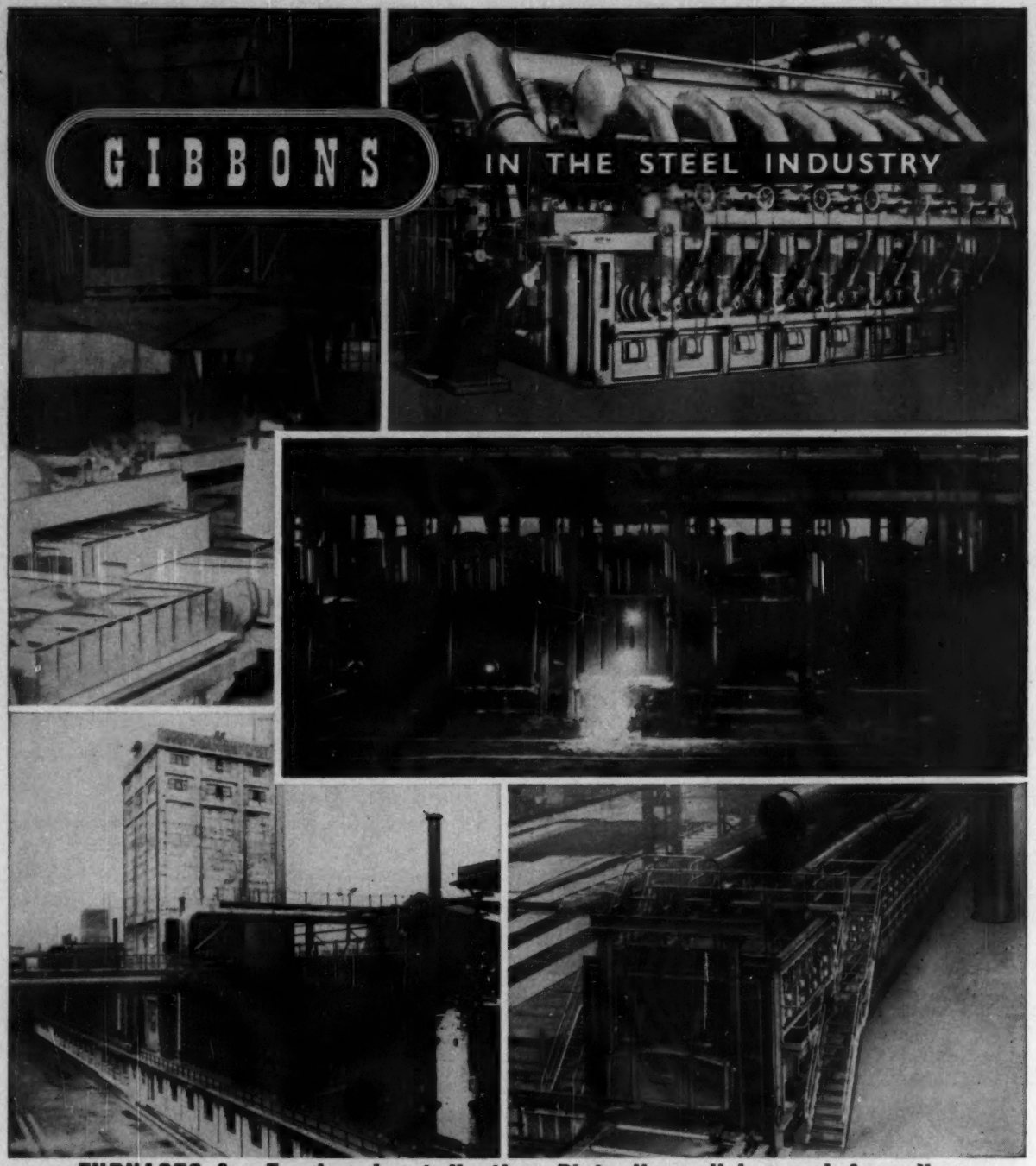

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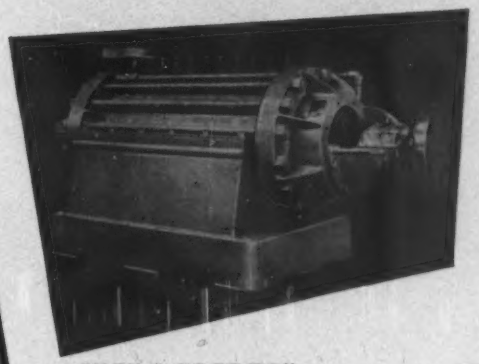

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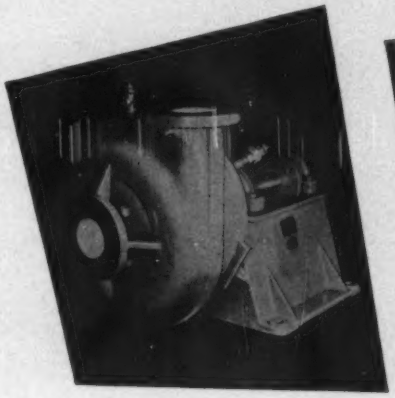
Robustly constructed pumps of high efficiency and reliability for waterworks, hydraulic services, mine dewatering, steel descaling, etc., etc.



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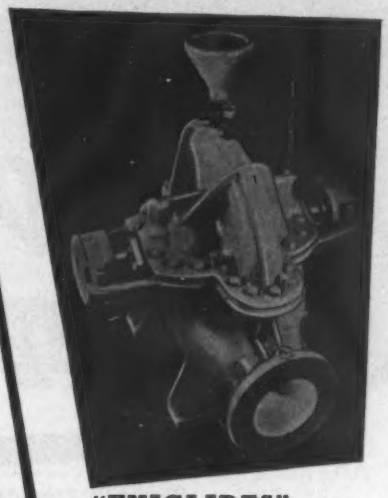
All-purpose single stage service pumps for low head duties in industry and public services.



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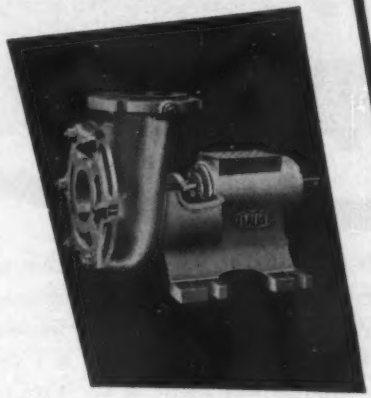

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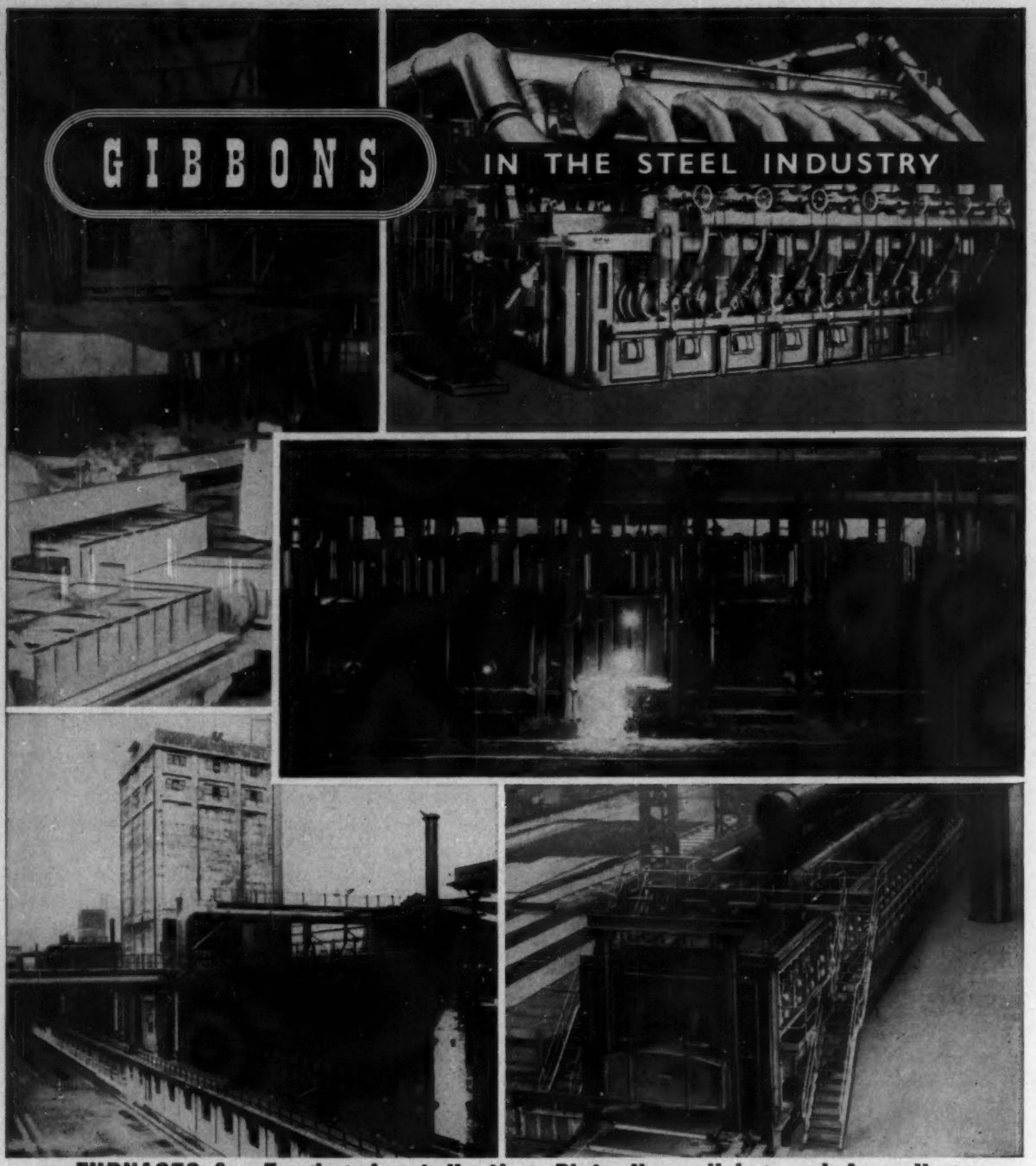
P.302 "A"



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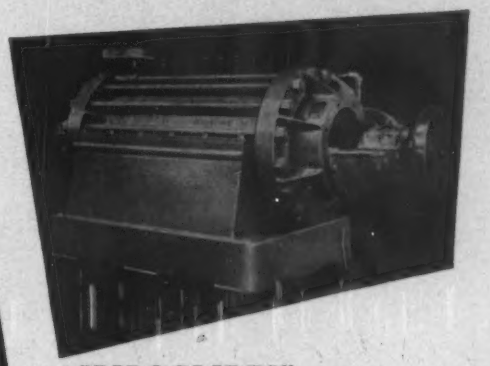

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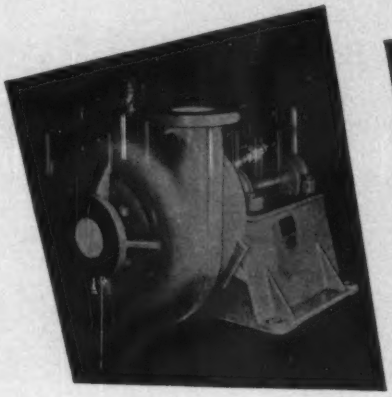

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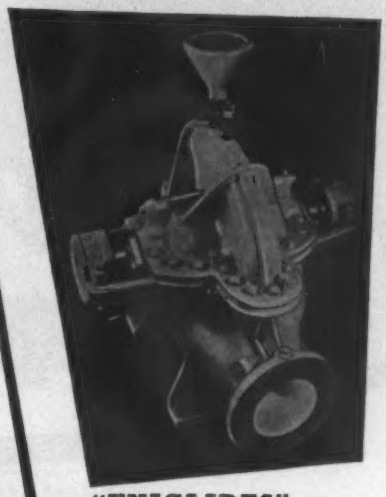

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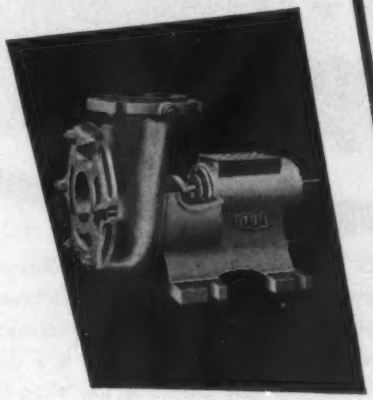

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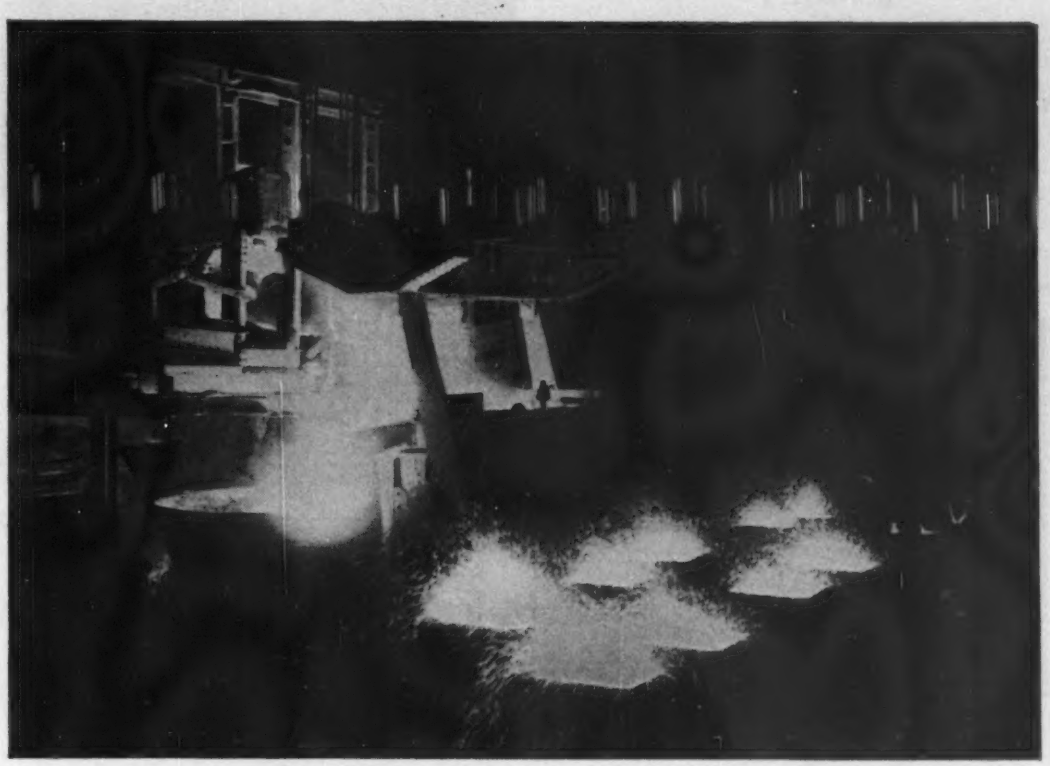

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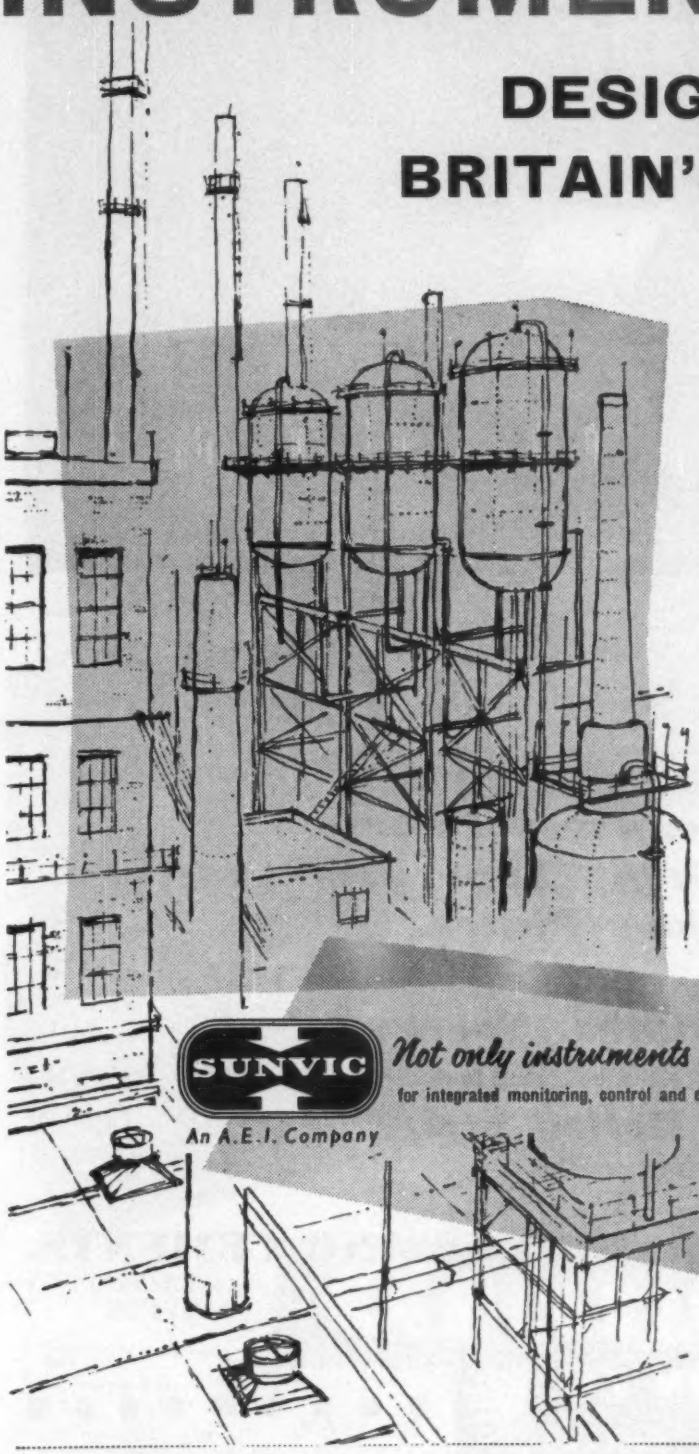

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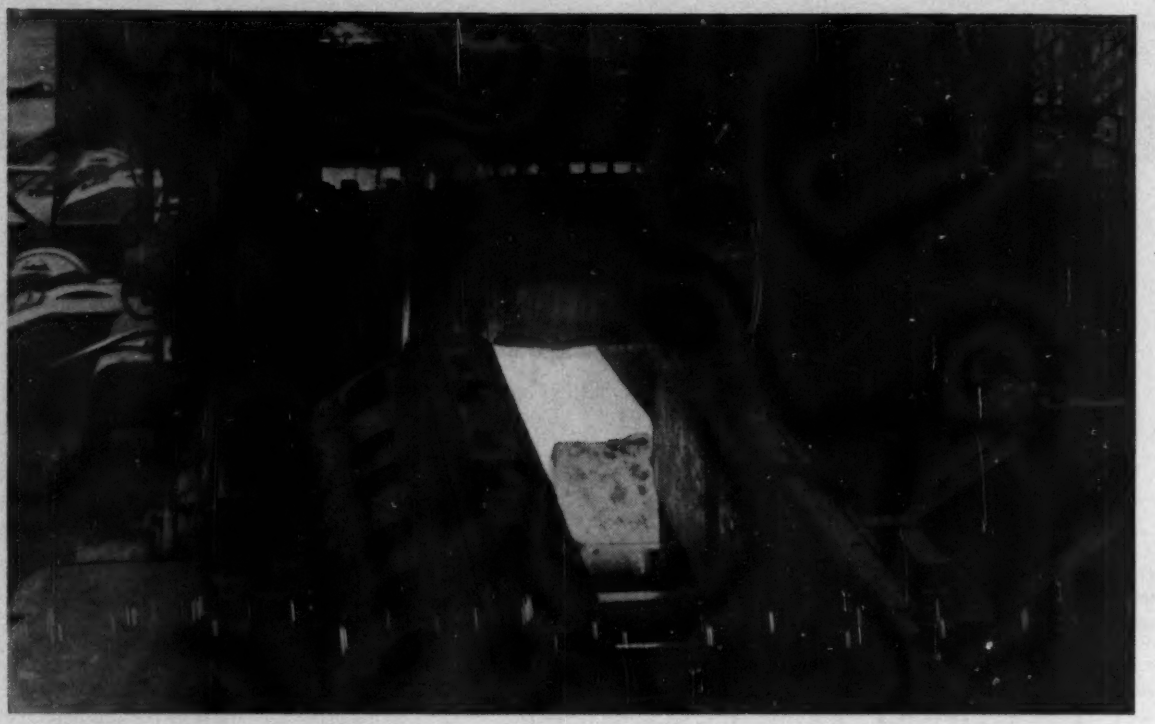

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1 *'Lumpy going'—half-way down hearth.*
2 *Men removing throat armour.*
3 *Cat Traxcavator commencing digging. Cast House Floor Level.*
4 *The break out.*

1

Scenes of operations at No. 1 Blast Furnace
(photos by permission of John Summers & Sons Ltd., Shotton)

Furnace blown out	23rd April 1958
Demolition commenced	26th April 1958
Demolition completed	13th May 1958

TOTAL TIME wrecking burden, lining, hearth and bear
18 DAYS
(contract carried out in association with Salem Engineering Co. Ltd.)

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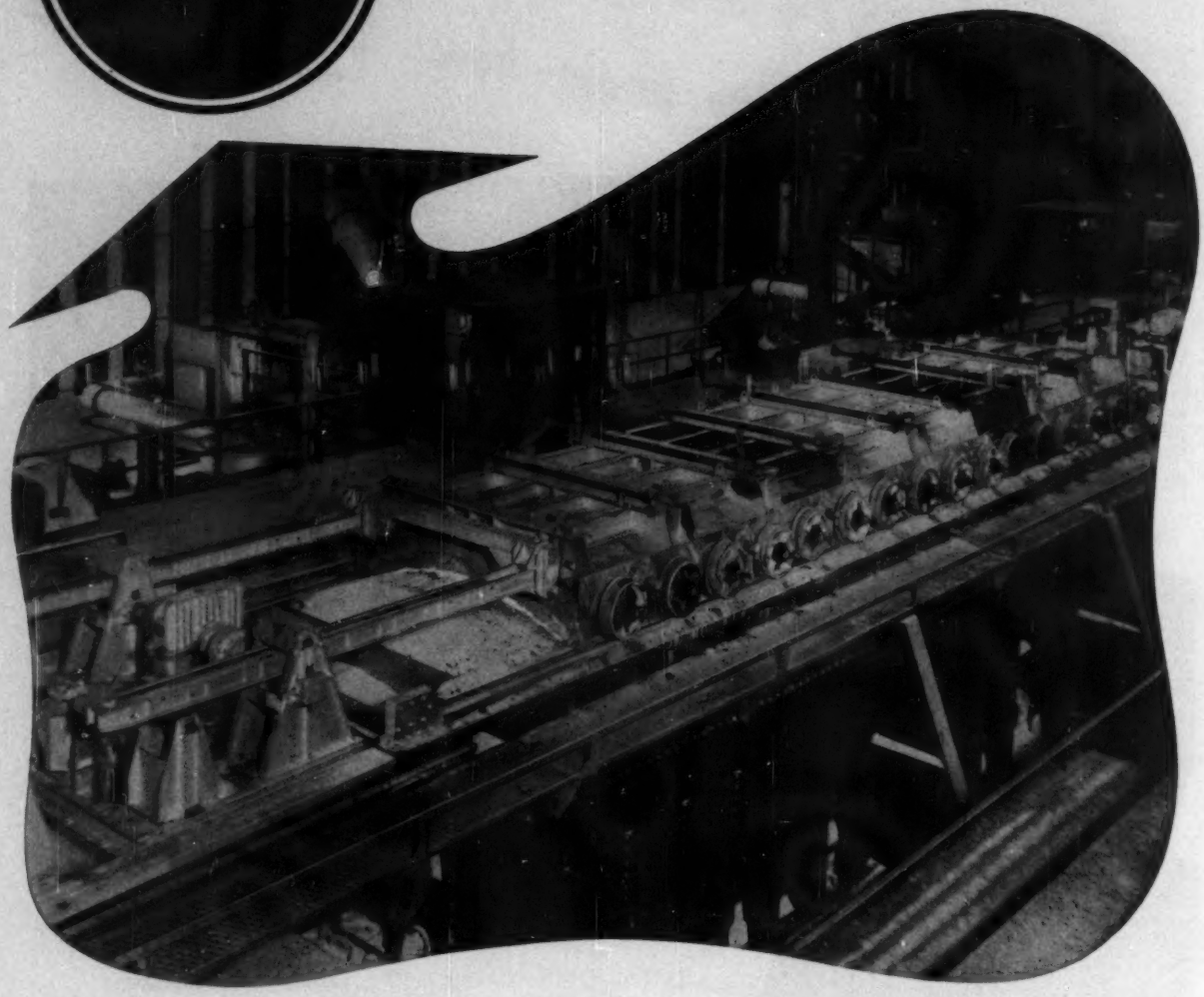

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The above illustrates one of a battery of blast furnace gas fired reversing regenerative Soaking Pits, each with a holding capacity of 120 tons.

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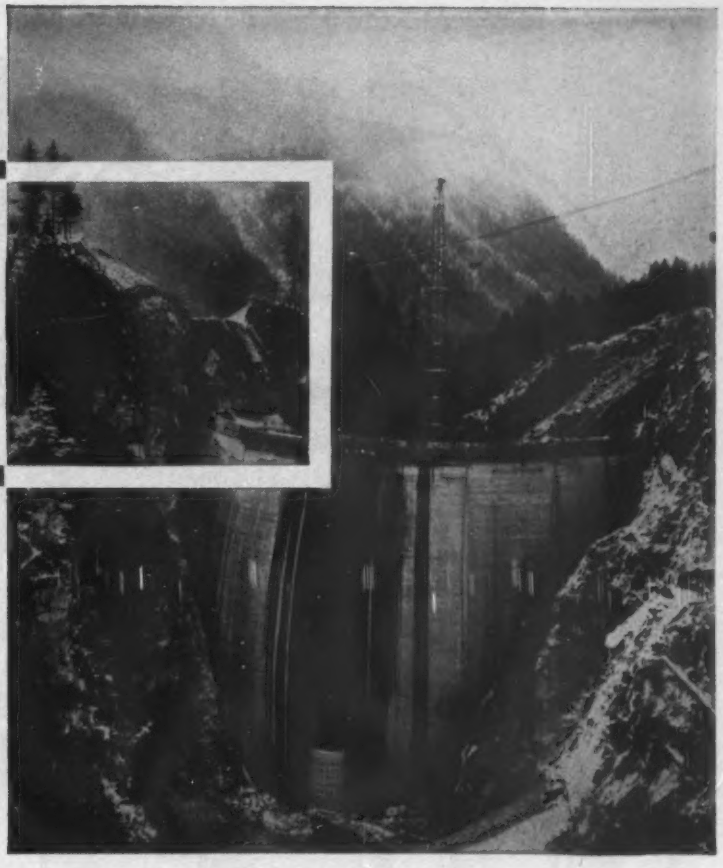

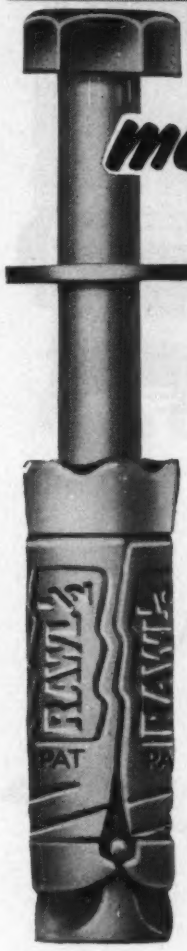

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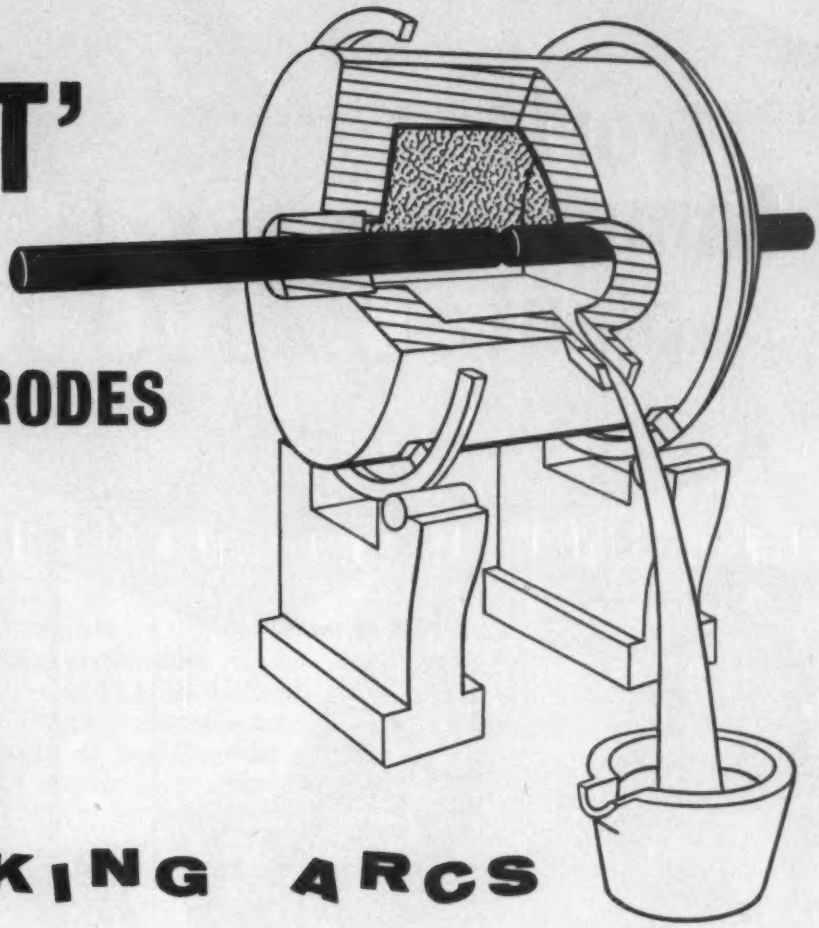

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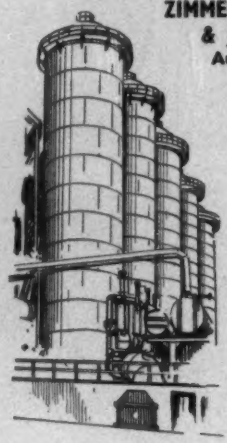
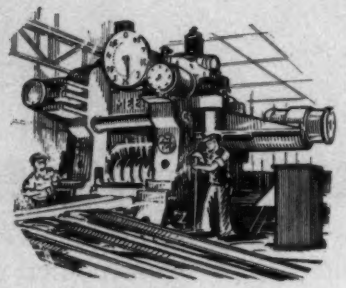
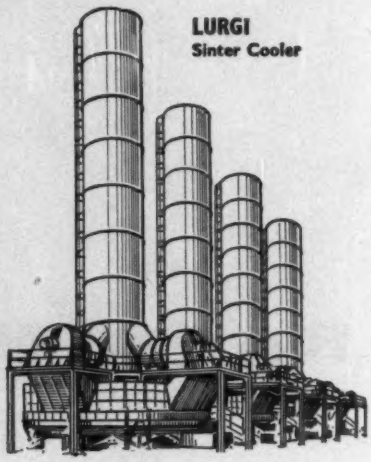


MEER AG Plug Mill



LURGI Sinter Cooler



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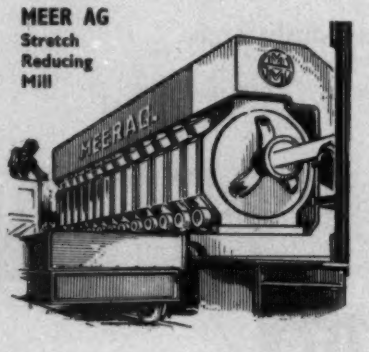

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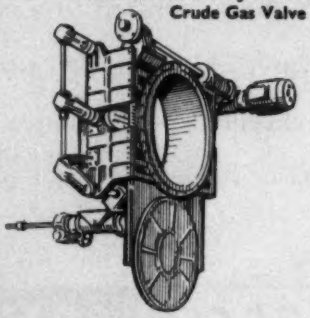

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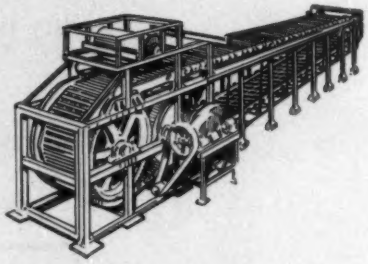

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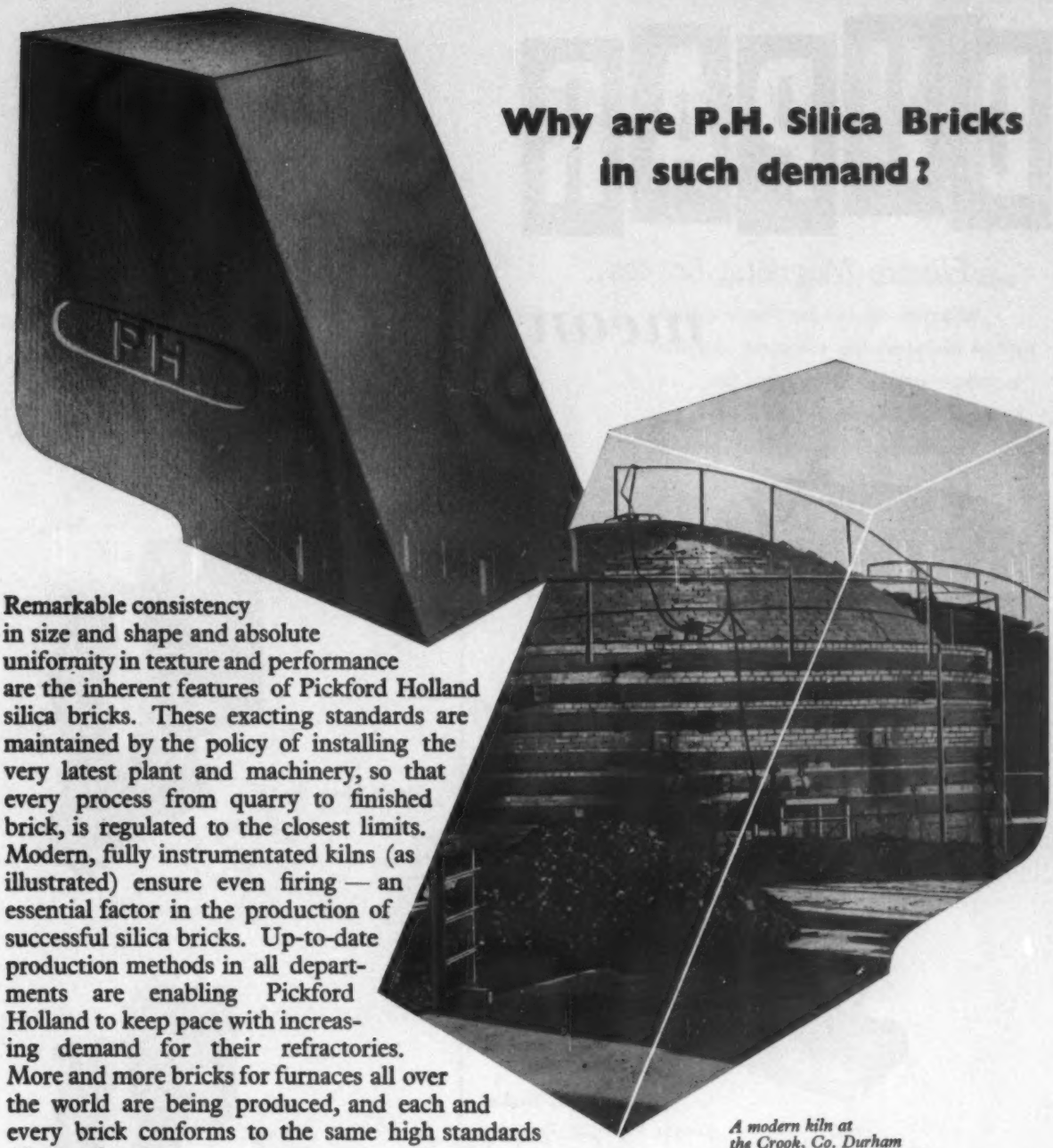

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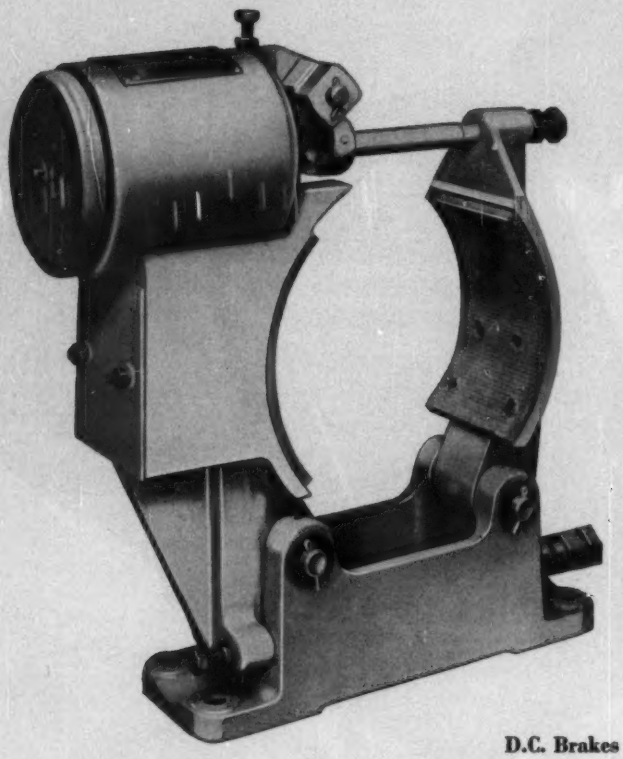

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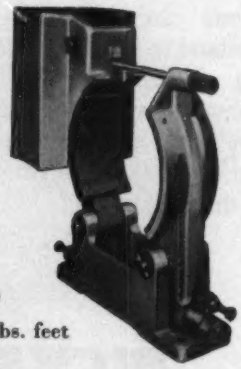

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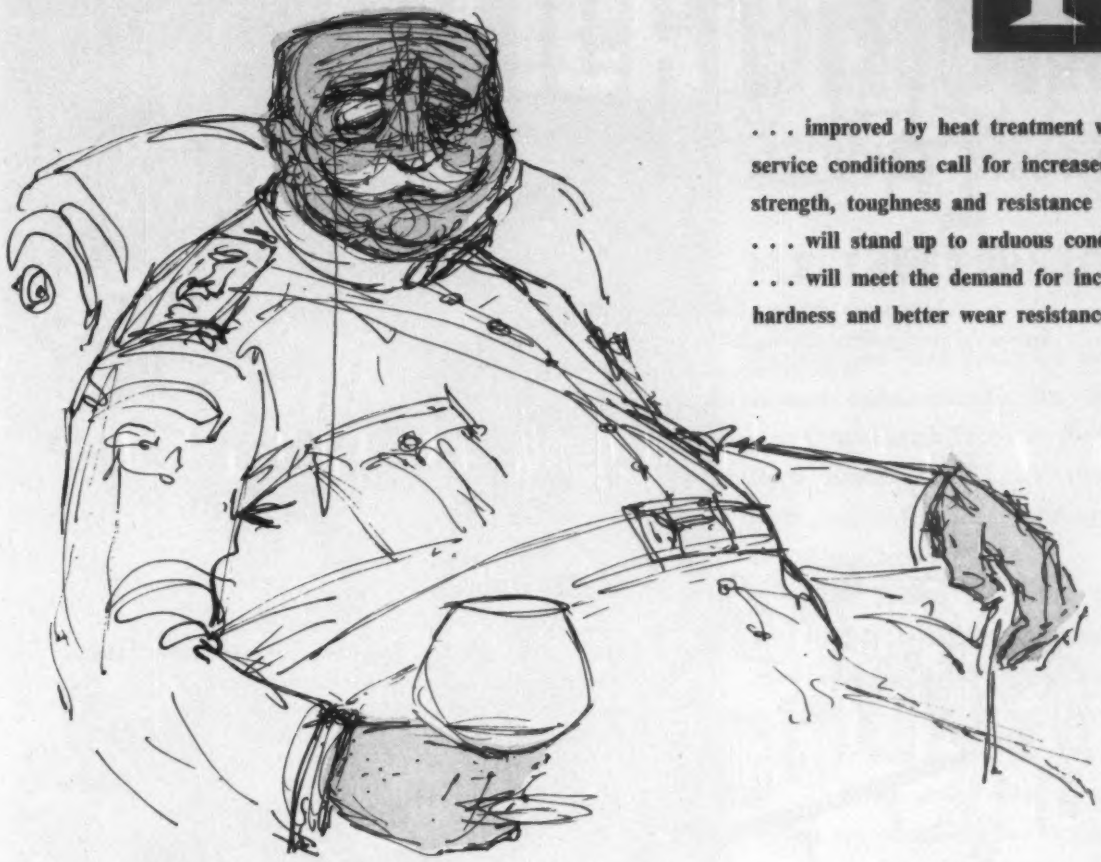

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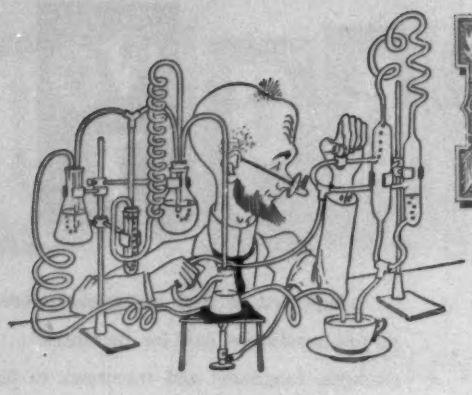

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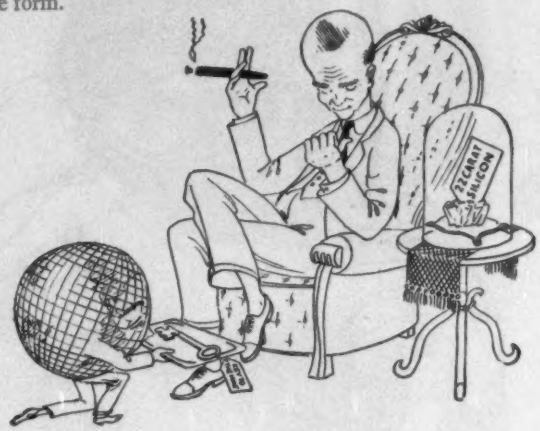
the eminent Swedish scientist, Berzelius, made the world's first ferro silicon, and 14 years later he succeeded in making the first silicon metal, although it was in an impure form.

in 1870 . . .

Volten improved upon the method then known for making ferro silicon, and he succeeded in producing an alloy with as high as 22 per cent silicon content.



since that time . . .

great strides have been made in the production of this alloy to keep pace with demands which ever increased as the remarkable metallurgical advantages of using ferro silicon in the making of steel became more generally known. Continual progress has also been made in the supply position of ferro silicon . . .

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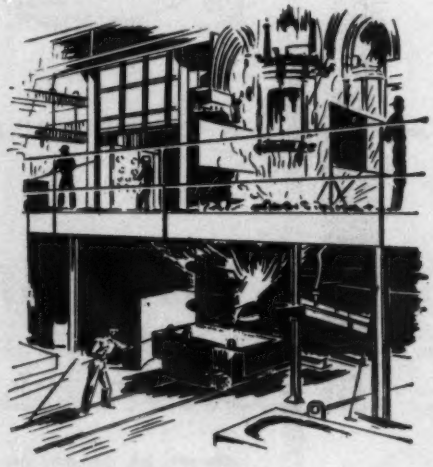

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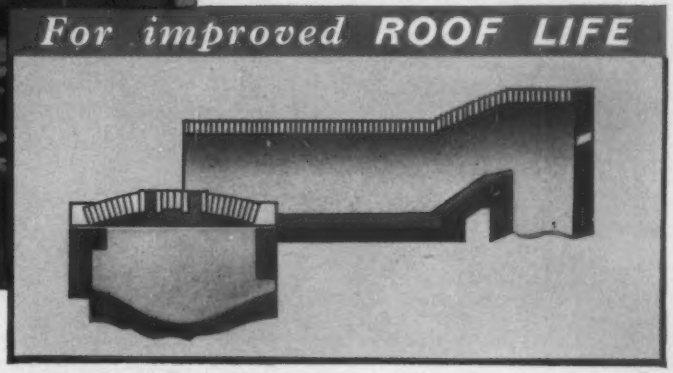

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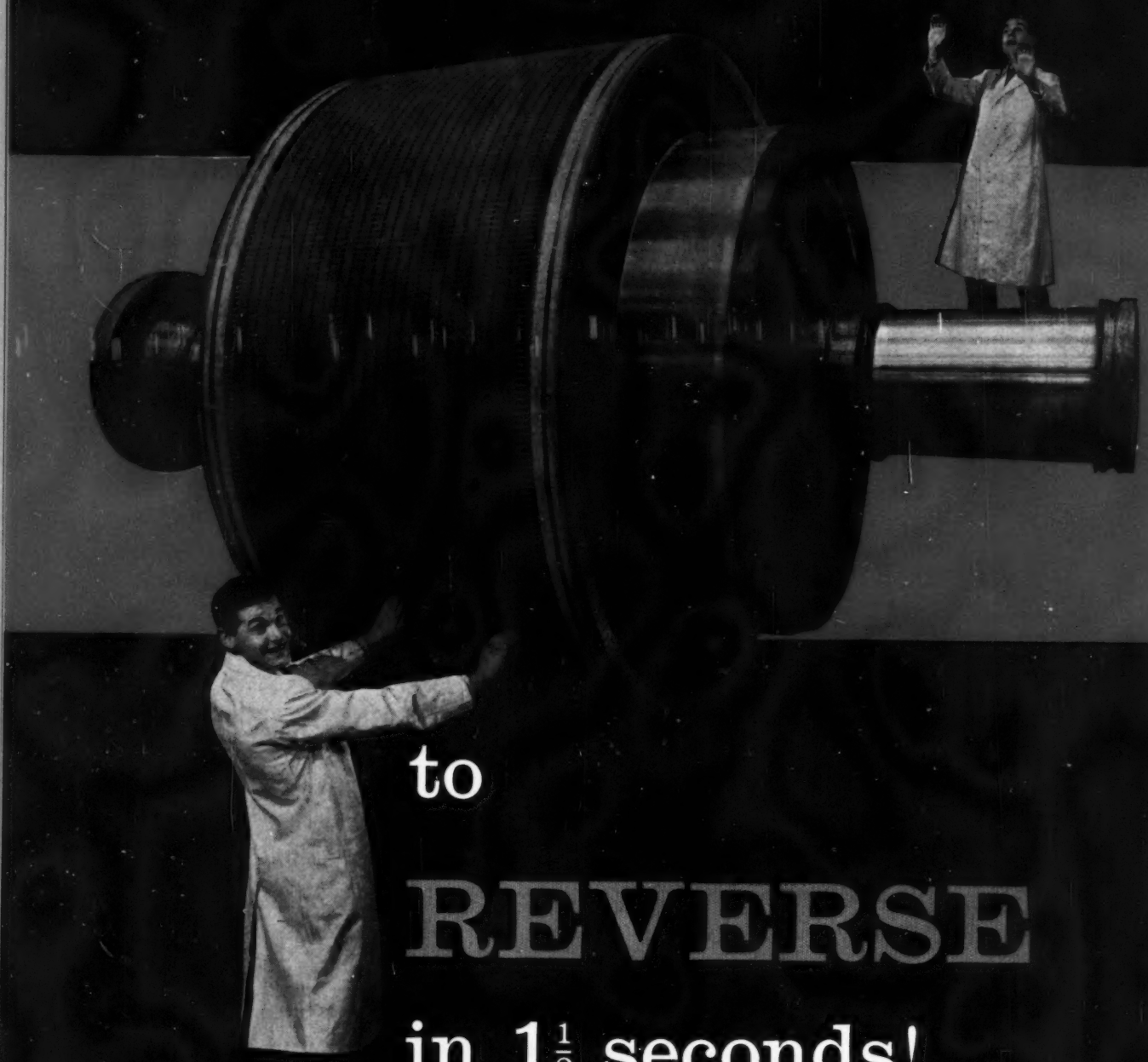

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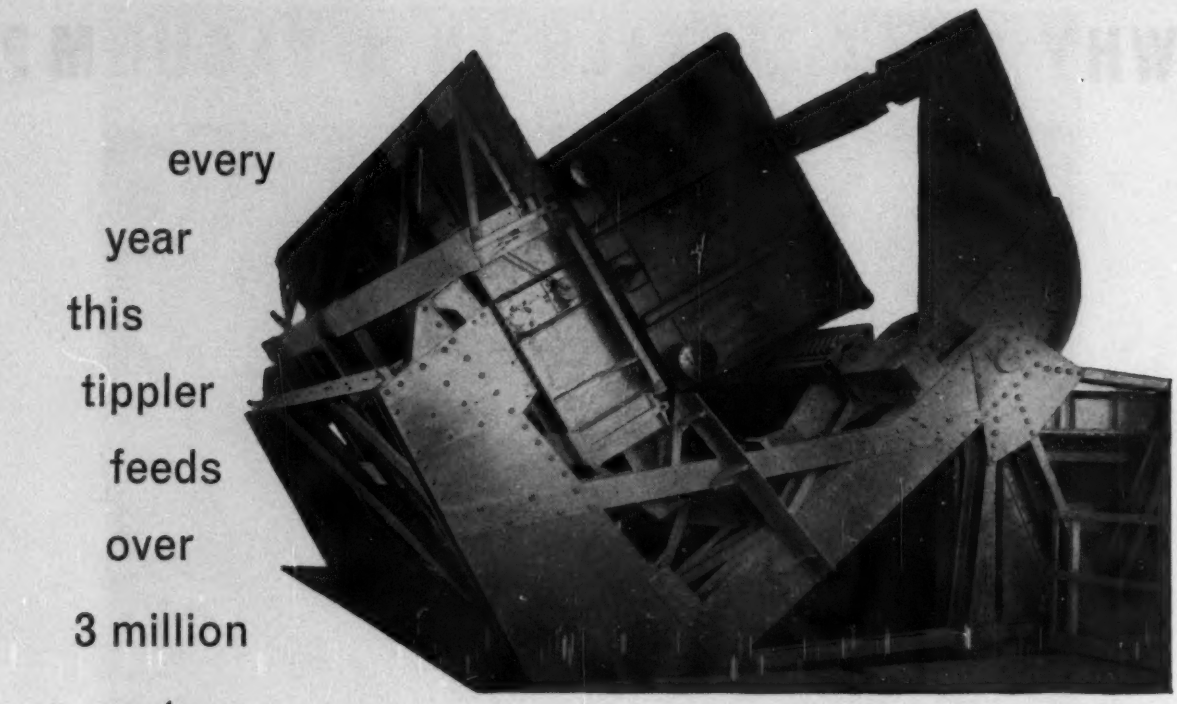

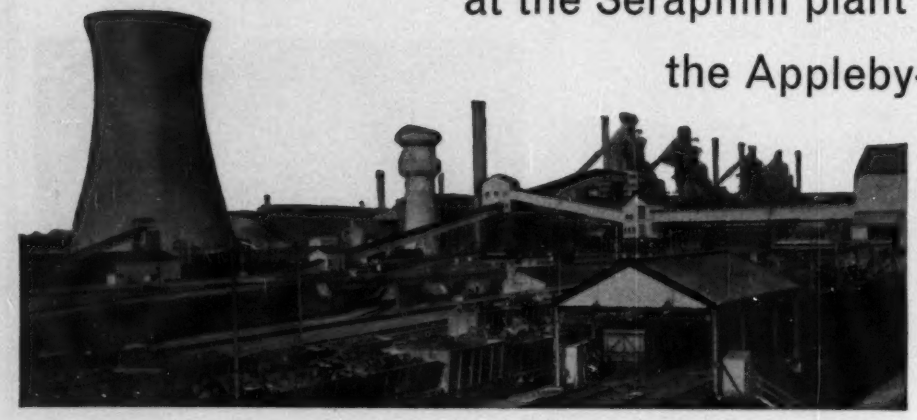

This complete ore-handling plant was commissioned in 1954 and is typical of many materials handling systems which have been installed all over the world.

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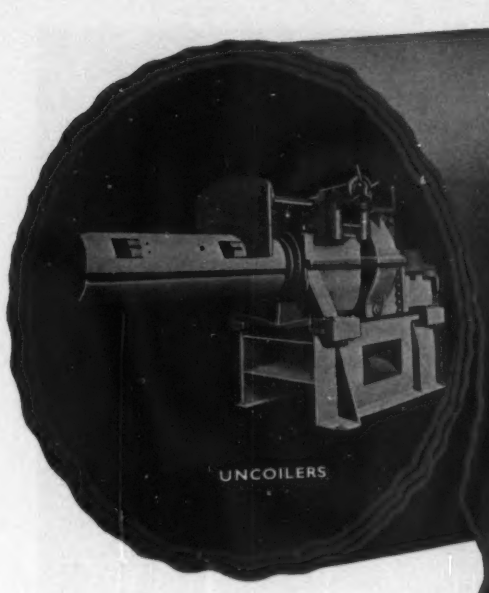

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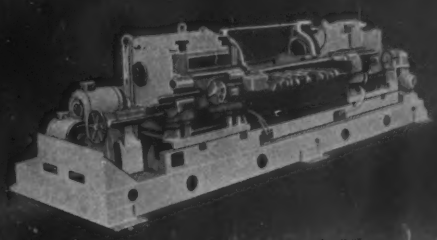

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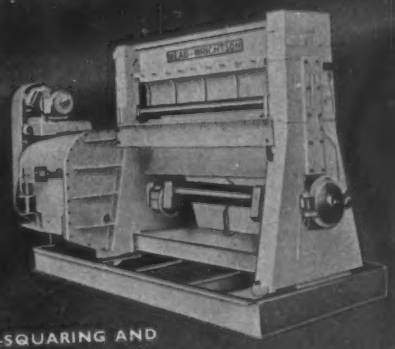

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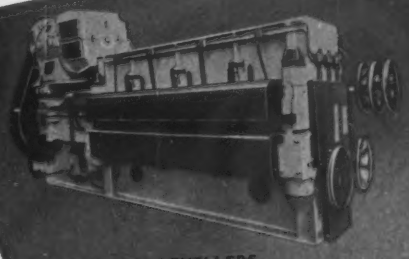

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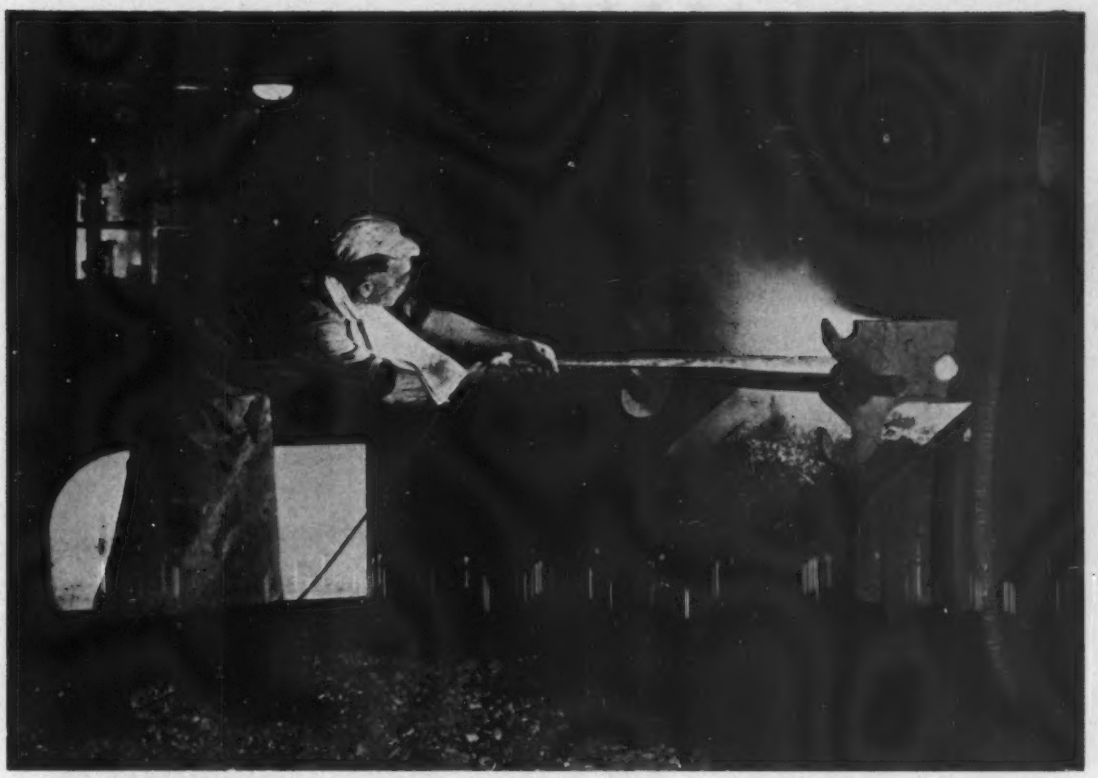

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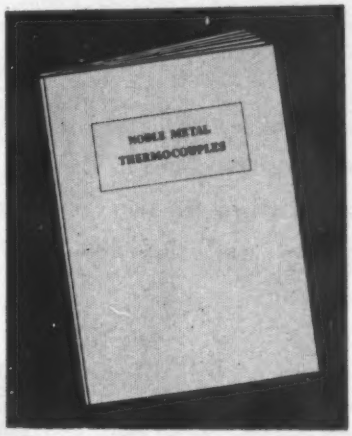

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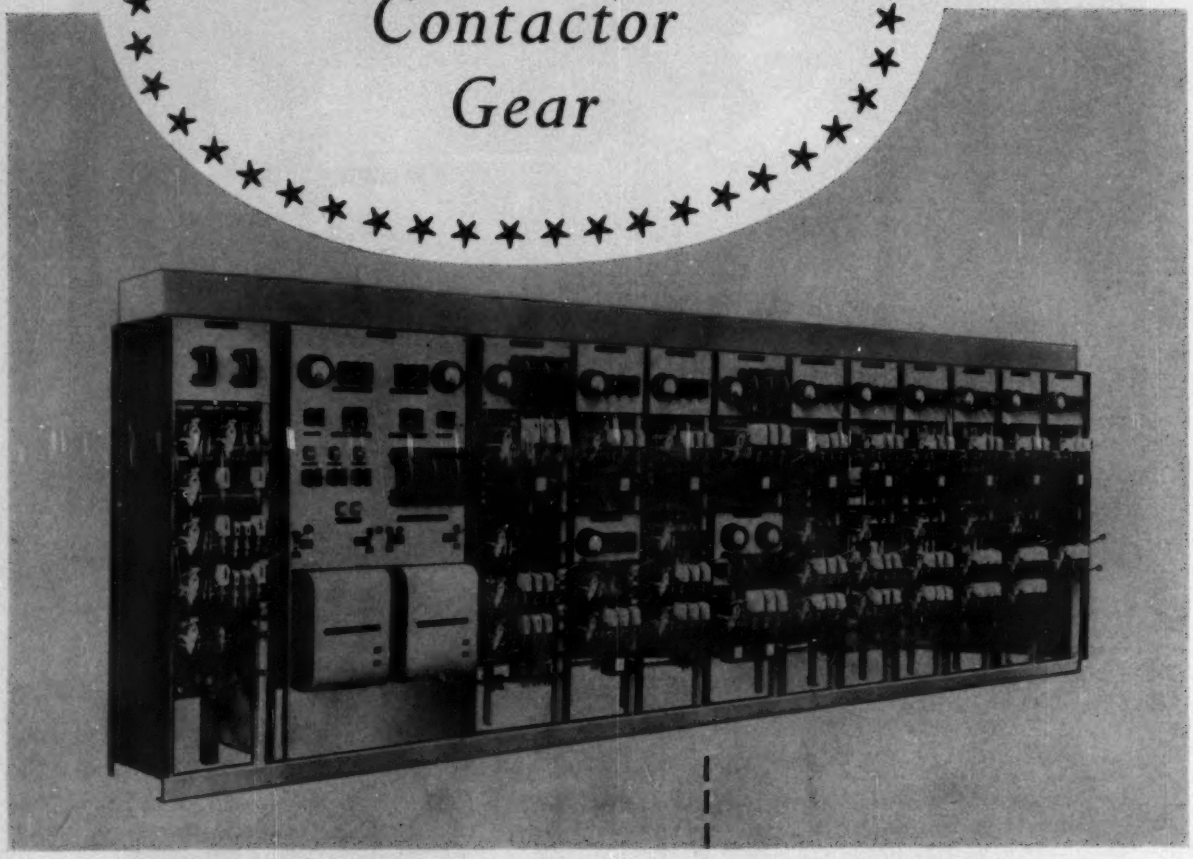

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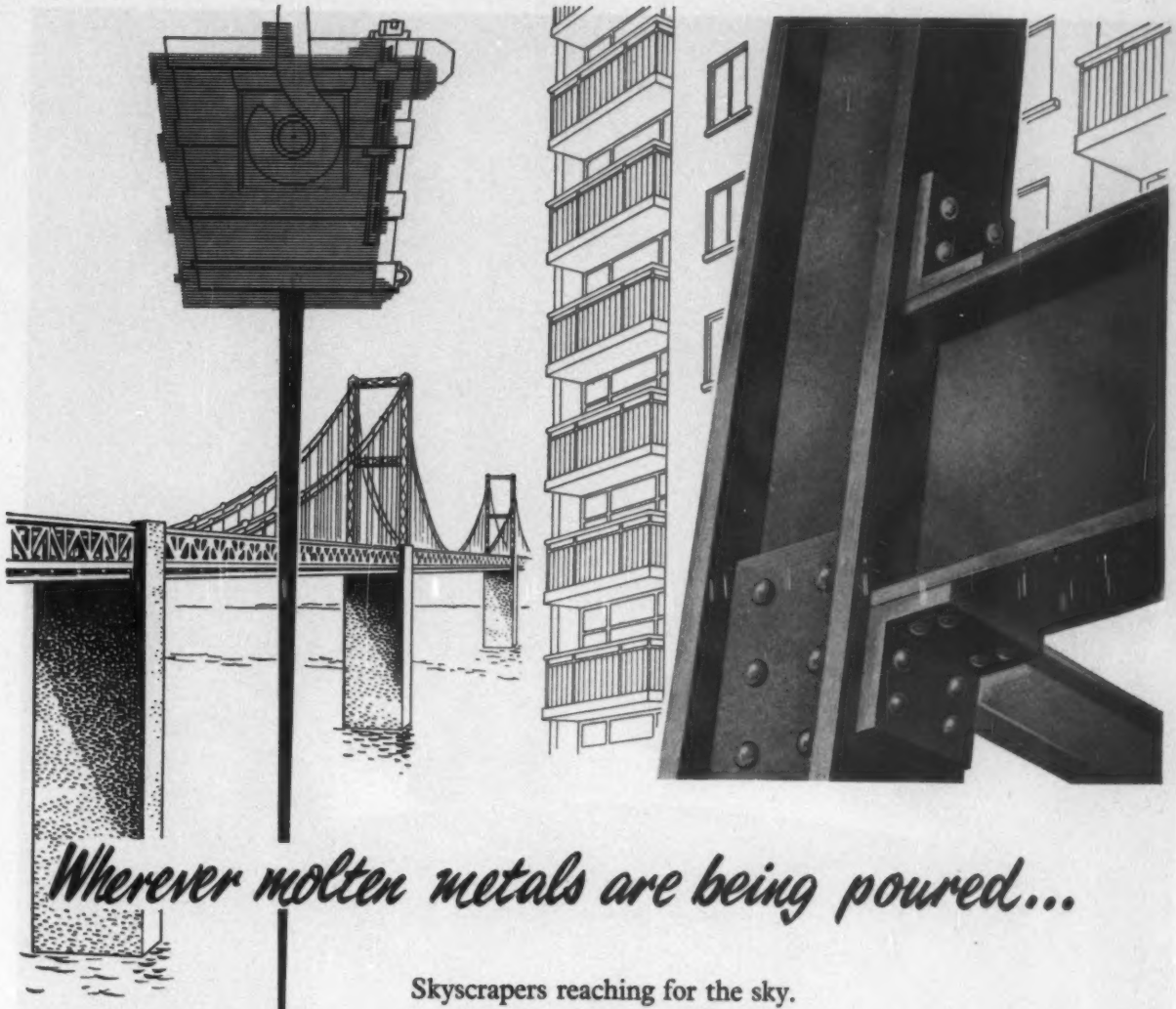

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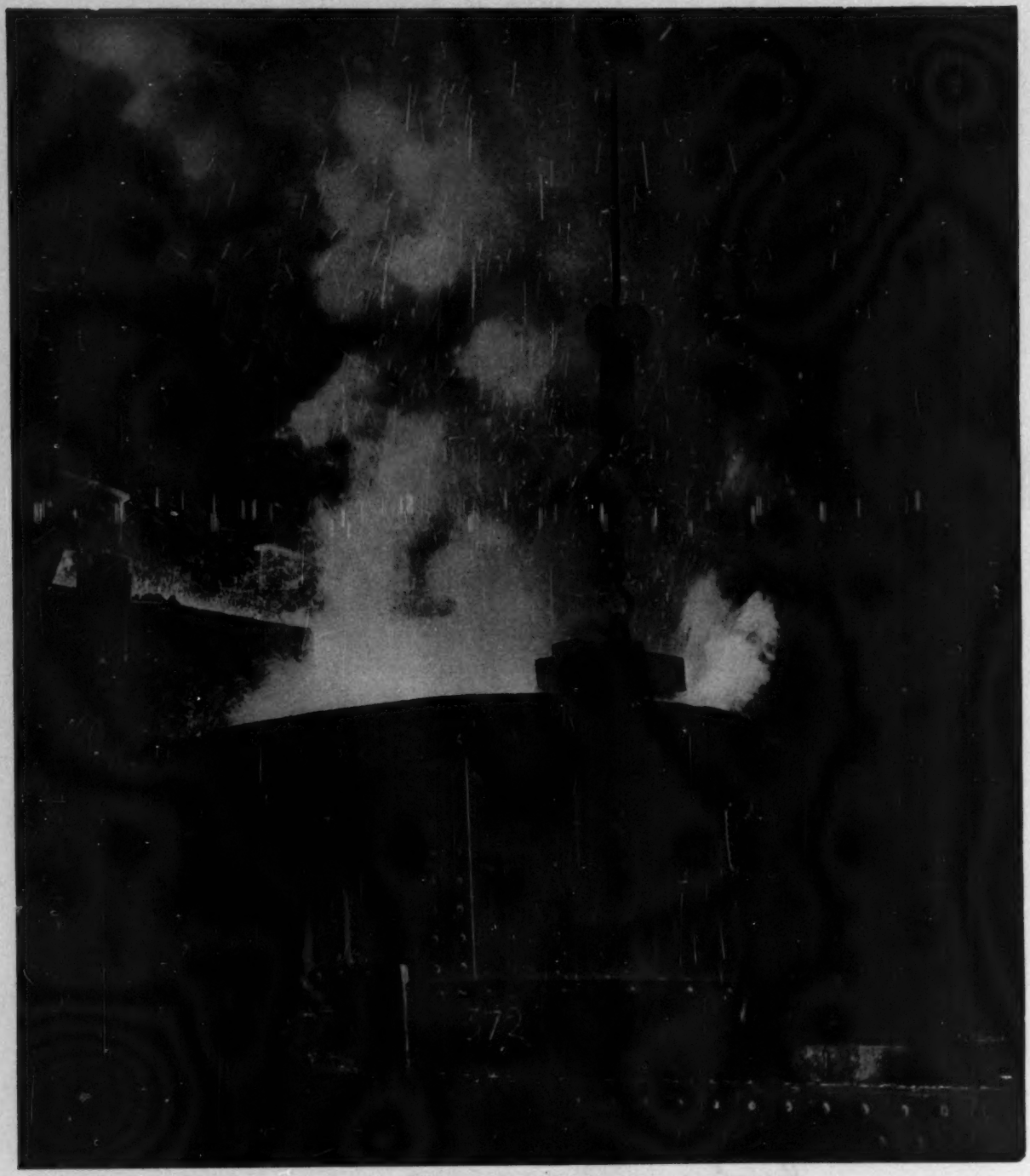

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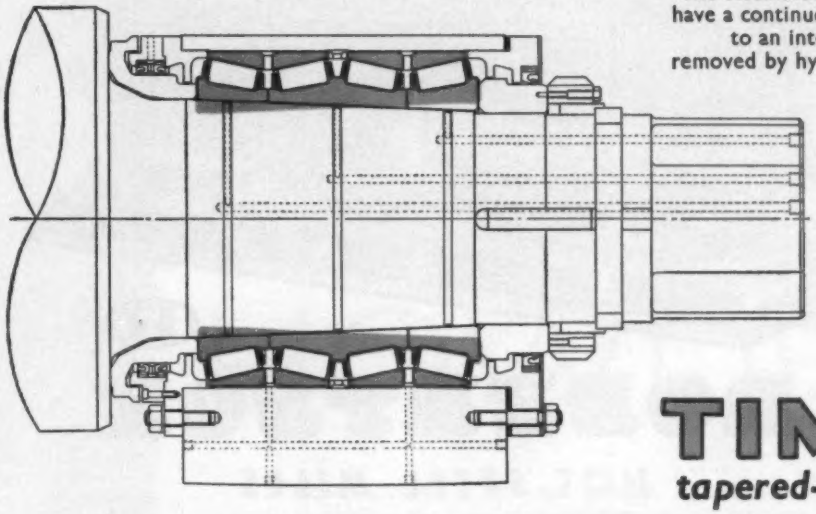

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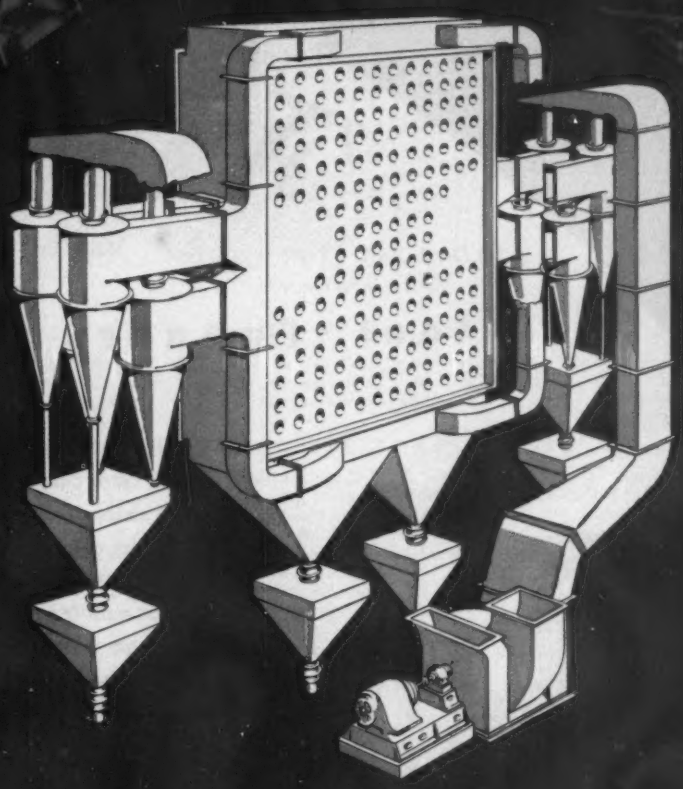

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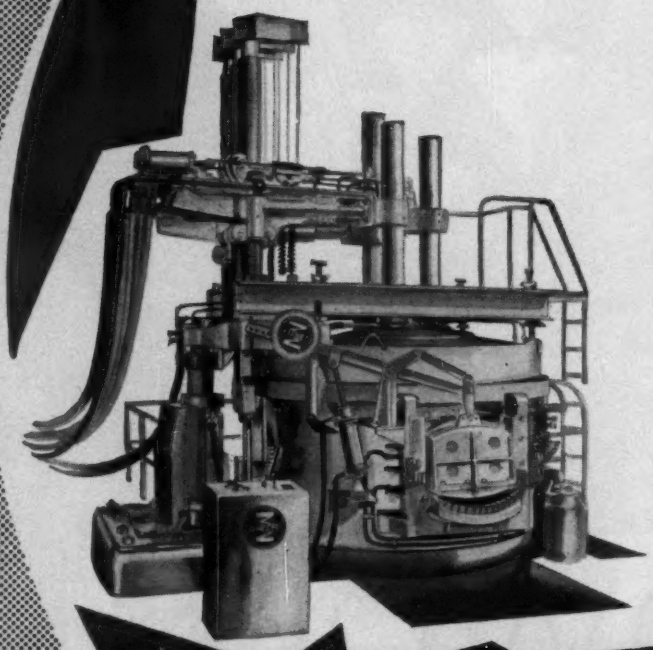

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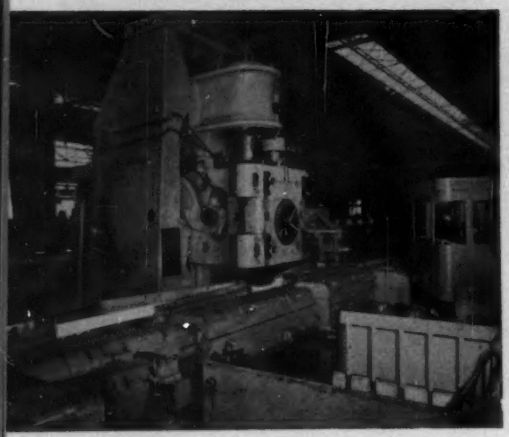
THE IRON AND STEEL INSTITUTE, 4 GROSVENOR GARDENS, LONDON, S.W.1

The Blooming and Slabbing Mill in action at Lackenby.

DAVY-UNITED AT DORMAN LONG

The new Davy-United 52″ x 112″ Reversing Blooming and Slabbing Mill now in production in the Lackenby Works of Dorman Long (Steel) Ltd., and the largest of its type so far installed in Britain. Capable of rolling ingots weighing up to 20 tons, it forms the primary unit of a new plant for producing universal beams which Dorman Long expect to bring into full operation this year.

Driven by twin 4,000 h.p. motors, each capable of developing up to 12,000 h.p. on peak loads, the mill utilizes 100 ton roll housings of 700 sq. ins. post area and incorporates a number of novel features, including a special design of manipulator tilting mechanism, hydraulic roll relieving gear and duplex roll changing. It was supplied along with a 1,350 ton hydraulic Hot Bloom and Slab Shear and all necessary handling, Transfer and auxiliary equipment.



The 1350 ton Hot Bloom and Slab Shear is of the open gap type, powered by triple ram hydraulic pumps and air loaded accumulator. Its main frame is a single piece steel casting weighing 145 tons.

DAVY-UNITED

Sheffield
Middlesbrough
Glasgow

243/D.U.C.

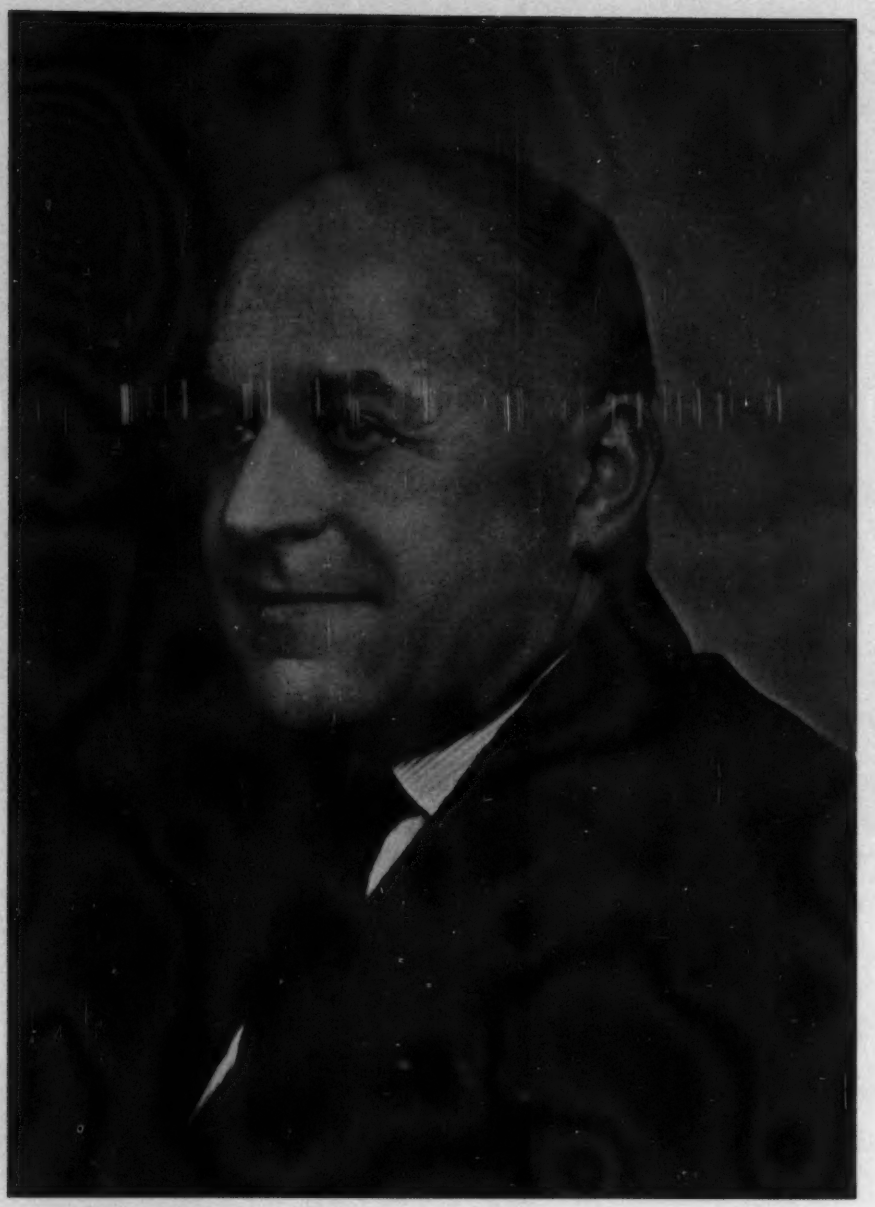
H. HARRIS, Ph.D., B.Sc., D.I.C., A.R.C.S.

HERBERT HARRIS was born in 1902 and educated first at the grammar schools of Accrington and Barrow-in-Furness and later at the Imperial College of Science and Technology where he gained his D.I.C., A.R.C.S., and B.Sc. degree. After three years post-graduate research work in physical chemistry he was awarded his Ph.D. degree.

Dr. Harris was appointed Lecturer in Physical Chemistry at the University of Bristol, a post which he left to gain industrial experience in the U.S.A., first with the Research Department of the International Telephone and Telegraph Laboratories, Inc., and then with the A. O. Smith Corporation.

In 1935 he returned to the U.K. to join Babcock and Wilcox Ltd., at Renfrew, where he is now Chief Metallurgist.

Dr. Harris has been a member of The Iron and Steel Institute since 1935. He has also had a long association with the Welding Research Council and he is Vice-Chairman of the Research Board of the British Welding Research Association. He is a member of the West of Scotland Iron and Steel Institute and was elected its President for the period 1957–59. As such he is serving as an Honorary Member of Council of The Iron and Steel Institute during his term of office.



H. Harris, Ph.D., B.Sc., D.I.C., A.R.C.S.

Honorary Member of Council 1957–59

PROCEEDINGS OF

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Air and Water Pollution in the Iron and Steel Industry

By A. Parker, C.B.E., D.Sc., F.R.I.C., M.I.Chem.E.

SYNOPSIS

Though much attention has been given to the problems of reducing the quantities of pollutants carried by gaseous and liquid effluents discharged from the many processes in the iron and steel industry, satisfactory methods of dealing with some of the problems at reasonable cost have not yet been found. The legislative requirements are explained in this paper, and attention is drawn to improvements that have been made during recent years, to investigations in progress, and to the difficulties still to be overcome. 1594

INTRODUCTION

ON AVERAGE, the human adult breathes about 30 lb of air each day and drinks 3–4 lb of water. Unless the air and water available are of reasonable purity, public health can be seriously affected and there can be costly damage to structures and materials of many kinds and to general amenities. Further, many industries are dependent for their successful operation on plentiful supplies of air and water of good quality.

The effects of air pollution on health have been tragically shown at times of dense fogs or 'smogs', when meteorological conditions have provided little natural ventilation, such as occurred in the Meuse valley in Belgium in 1930, in Donora in the United States in 1948, and in London in 1952 and 1956. In London in December, 1952, four days of smog caused the deaths of 4000 people and the less severe smog in January, 1956, caused 1000 deaths. The effects of contaminated water on health have been demonstrated in this country and elsewhere by epidemics of such diseases as paratyphoid.

It is difficult to assess damage to health, with its effect on human efficiency, in terms of financial cost. Estimates of the cost of damage, mostly to materials and structures, caused by air pollution have been made in several countries. The Committee on Air Pollution under the chairmanship of Sir Hugh Beaver, whose reports were issued in 1953 and 1954, estimated that the cost of the damage caused by pollution of the air in the U.K. is at least £250 million a year; this estimate did not take into account the cost of treatment of the air supplies for many buildings, including factories making delicate products such as photographic materials. There have been no trustworthy estimates of the cost to the community of the damage caused by water pollution, including the expense necessarily incurred in obtaining supplies from distant sources and in treating polluted waters to render them fit for human consumption and for use in industrial processes, but the overall cost must be great.

It is thus clear that considerable expense is justifiable in efforts to mitigate the pollution of the air and of natural waters. There is no doubt that much improvement can be achieved at reasonable cost. In some instances, as experience has shown, efforts to reduce pollution can lead in industry to an improved yield of the main products or to the recovery of valuable by-products or both, with resulting increased overall efficiency and direct financial savings. Pollutants are often valuable materials that should be in the products of manufacture and not discharged in the waste gases and liquids.

At the same time, it must be recognized that on the basis of existing knowledge it is not economically possible entirely to prevent the pollution of air and water in a country so highly industrialized and so densely populated as the U.K. Any serious attempt to stop all pollution would involve shutting down some industries and so great a reduction in activity that it would be impossible to maintain the population of this

The author is a Chemical Engineering Consultant.

country at the present standard of living. Inability to attain the ideals of unpolluted air and water, however, is not accepted as a justification for the uncontrolled discharge of waste materials.

The evils of pollution have long been recognized in this country, especially during the last 150 years with the great increase in the population and the rapid expansion of industry. At the beginning of the nineteenth century, the U.K. was mainly agricultural in character, with a population of only 10 or 11 millions, and there was relatively little industry in the modern sense, as indicated by the fact that the consumption of coal was no more than about 12 million tons a year. The population is now five times as great at about 50 millions and the consumption of coal, oil, and hydro-electricity is equivalent to more than 250 millions tons of coal a year or twenty times as great as 150 years ago.

In addition to rights under common law in the U.K., from time to time over the centuries there have been special legislative measures aimed at preventing or mitigating pollution of the air and of natural waters, but in general these special measures have not been so effective as was desirable in the national interest as a whole. In recent years, legislation has been strengthened and industry is faced with obligations that must be considered in siting, planning, equipping, and operating works and factories and many commercial premises. Many industries now recognize their obligations and realize that mitigation of air pollution and water pollution so far as is economically practicable in the national interest is, in the long view, also in their interest.

In industry generally, there are many technical problems still to be solved if real progress is to be made. Substantial improvement will not be achieved as rapidly as desirable and at reasonable cost, unless there is full co-operation in the exchange of knowledge and experience on the part of all concerned. In this respect, the iron and steel industry has set an excellent example. To facilitate co-operation, the Iron and Steel Engineers Group of The Iron and Steel Institute organized two well attended meetings in London, each occupying two days, at which papers were presented by authors not only from the U.K. but also from several other countries. There were full and excellent discussions at both meetings, which were well planned and organized.

At the first meeting in September, 1957, there was an address of welcome by the President of the Institute, Mr. A. H. Ingen-Housz, to an audience of nearly 400, then an opening address by the Chairman of the Iron and Steel Engineers Group, Mr. W. M. Larke, followed by the presentation and discussion of fifteen papers on various aspects of air pollution in the iron and steel industry. The second meeting, which was held in December, 1957 was on water pollution in the iron and steel industry and was attended by more than 250 representatives of many interests. After an opening address by Mr. W. M. Larke, ten papers were presented and discussed. All of the papers presented at the two meetings, with full reports of the contributions to the discussions, are now published by the Institute in one document as Special Report No. 61,* which contains a wealth of information and will be an acknowledged work of reference and guidance for a long time.

It would be impossible in this relatively short article to summarize the vast amount of information in Special Report No. 61. The object of this paper is to draw attention to the growing importance of greatly reducing the pollution of air and water supplies, to the principal legislative requirements, and to some of the technical problems facing the iron and steel industry in its efforts to effect improvements.

LEGISLATION

Under common law in the U.K. proceedings can be taken in the courts for damages caused by the emission of excessive quantities of airborne effluents such as smoke, grit and dust, and noxious or unpleasant liquid droplets, vapours, and gases. It is not usually easy, however, to prove damage to persons and property and in consequence it is not often that proceedings under common law have been instituted with success.

With regard to water pollution, the proprietor of land has at common law certain riparian rights in relation to watercourses that run through or abut on his land. Every riparian owner is entitled to the water of his stream in its natural flow, without sensible diminution or increase in quantity and without sensible alteration in its character or quality. As a result of decisions in the courts, it seems that this right applies not only to natural streams but also to tidal waters, underground waters, and to artificial channels of a permanent nature. It is clear from the condition of many of the rivers and streams in the U.K. that these riparian rights have not always been fully maintained.

In these days of great industrial activity, the industrialist is more often concerned in meeting the requirements of statutory legislation rather than common law. It is important, therefore, that he should know his obligations under the various statutes and what authorities are responsible for administering the statutes.

Air Pollution

So far as the iron and steel industry is concerned, the principal Acts now in force in relation to air pollution are the Alkali, Etc. Works Regulation Act, 1906 and the Clean Air Act, 1956.

Reference, however, should also be made to the Public Health Act, 1936, the Public Health (London) Act, 1936, and the Public Health (Scotland) Acts, 1897–1939. These several Acts contain similar provisions. The authorities responsible for enforcing the Acts in London are the London County Council and the metropolitan borough councils. In the rest of England and Wales, they are the councils of county boroughs, boroughs, and county districts, and in Scotland, town councils and county councils. Section 92 of the Public Health Act, 1936 constitutes as a statutory nuisance any dust or effluvia caused by any trade, business, manufacture, or process which is prejudicial to the health of, or a nuisance to, the

* "Air and Water Pollution in the Iron and Steel Industry," *Iron and Steel Institute Special Report* No. 61, 1958: 260 pp., price £4 5*s*. 0*d*., post free.

inhabitants of the neighbourhood. For the purpose of these provisions the expression 'dust' does not include dust emitted from a chimney as an ingredient of smoke. It is a defence to prove that the best practicable means have been taken for preventing or counteracting the effect of a nuisance, and a court shall have regard to cost and to local circumstances. It is worthy of note that a local authority cannot without the consent of the Minister institute summary proceedings under this part of the Act if proceedings for the offence might be taken under the Alkali Act, 1906.

Unlike the Public Health Acts and the Clean Air Act, the provisions of the Alkali Act, 1906 and the corresponding Act for Scotland are not enforced by the local authorities, but centrally by Alkali Inspectors appointed by the Ministry of Housing and Local Government for England and Wales and by the Department of Health for Scotland. With the additions made by Alkali Orders published in 1928, 1935, 1939, 1950, 1957, and 1958, the provisions of these Acts now relate to a very large number of processes carried out in numerous works in the U.K. These works include the following, of special interest in the iron and steel industry:

(i) Ironworks and steelworks in which (*a*) iron or ferro-alloys are produced in a blast-furnace and in which raw materials for use in blast-furnaces are handled or prepared, or (*b*) iron ores for use in blast-furnaces are calcined or sintered, or (*c*) iron or steel is melted in air or rotary furnaces fired by coal or oil, or in cupolas using a heated air blast, or in electric-arc furnaces, or (*d*) steel is produced, melted, or refined in Bessemer, Tropenas, open-hearth, or electric-arc furnaces, or (*e*) oxygen or air enriched with oxygen is used for refining iron or for producing, shaping, or finishing steel

(ii) Gas and coke works in which (*a*) coal, oil, or mixtures are handled or prepared for carbonization or gasification and in which these materials are subsequently carbonized or gasified, or (*b*) water gas is produced or purified, or (*c*) coke or semi-coke is produced and quenched, cut, crushed, or graded, or (*d*) gas produced by the carbonization or gasification of coal, oil, or mixtures is purified

(iii) Producer-gas works in which producer gas is made from coal and in which raw producer gas is transmitted or used

(iv) Tar works where gas tar or coal tar is distilled or heated and works in which creosote or other product of distillation of tar is distilled or heated

(v) Benzene works in which wash oil used for scrubbing coal gas is distilled or crude benzole is distilled

(vi) Acid-sludge works in which acid sludge from the refining of coal tar or other hydrocarbon derivatives is so treated as to cause the evolution of noxious or offensive gases

(vii) Sulphate of ammonia and muriate of ammonia works.

Under the Alkali Acts, the defined processes must not be operated until the owner has obtained a certificate of registration, which must be renewed annually. Before registration is granted, the Chief Alkali Inspector has to be satisfied that the best practicable means have been provided to keep to the minimum the emission of noxious or offensive gases. After registration, the best practicable means must be maintained in good order and used continuously.

The Clean Air Act, 1956, relates only to the mitigation of air pollution by smoke, and grit and dust from equipment burning fuel. In this respect it is the most important of the general legislative measures. It prohibits the emission of dark smoke for periods longer than may be specified by regulations by the Minister of Housing and Local Government for England and Wales and the Secretary of State for Scotland, from (*a*) a chimney of any building, (*b*) railway locomotive engines, and (*c*) vessels in certain navigable waters.

By the Dark Smoke (Permitted Periods) Regulations, 1958, emission of dark smoke from any chimney is permitted for not longer than 10 min in the aggregate in any period of 8 h, or, if soot-blowing is carried out within such period, for not longer than 14 min in the aggregate. For a chimney serving two furnaces the periods of 10 and 14 min are increased to 18 and 25 min respectively, for a chimney serving three furnaces they are increased to 24 and 34 min, and for a chimney serving four or more furnaces they are increased to 29 and 41 min. The continuous emission of dark smoke, caused otherwise than by soot-blowing for more than 4 min, or the emission of black smoke for more than 2 min in the aggregate in any period of 30 min contravene the regulations. It is important to note that a single boiler or unit of industrial plant fired by more than one furnace discharging to the same chimney is deemed to be one furnace for the purpose of the regulations. Dark smoke is defined as smoke as dark as or darker than shade 2 of the Ringelmann chart and black smoke means smoke as dark as or darker than shade 4 of the chart.

In proceedings in relation to the emission of dark smoke, it is a defence to prove (*a*) that the contravention was due to the lighting up of a furnace which was cold, or (*b*) that it was due to some failure of equipment that could not have been foreseen, or (*c*) that it was due to the use of unsuitable fuel, suitable fuel being unobtainable. Until July, 1963, it is also a defence to prove that the contravention was due to the nature of the building or its equipment and that it had not been practicable to alter or equip the building so that it could be fully used without the likelihood of contraventions.

No new industrial furnace can be installed of a heating capacity greater than 55,000 B.t.u./h without prior notice to the local authority and such furnace should as far as practicable be capable of continuous operation without emitting smoke when burning fuel of a type for which it was designed. No new furnace to burn pulverized fuel in any quantity, or to burn solid fuel or waste in any other form at a rate of one ton or more per hour can be installed unless the furnace is provided with plant approved by the local authority for arresting grit and dust. It is also the duty of the local authority in approving plans for an industrial chimney intended to carry smoke, grit, dust or gases to be satisfied that the height of the chimney will be sufficient to prevent, so far as practicable, the discharge from becoming prejudicial to health or a nuisance, having regard to all the circumstances.

It is important to note that without the consent of the Minister no proceedings can be brought under the Clean Air Act in relation to emissions of smoke, grit, and dust from premises or processes controlled under the Alkali Acts. The Alkali Acts, however, now have effect in relation to smoke, grit, and dust as they have in relation to noxious or offensive gases, and local authorities will no doubt watch carefully to see that boiler furnaces and similar furnaces in premises controlled by the Alkali Acts are not more favourably treated than in premises directly under the control of the Clean Air Act.

Water Pollution

So far as industry is concerned, the most important Acts in relation to the discharge of trade effluents into sewers or watercourses are now the Public Health (Drainage of Trade Premises) Act, 1937, the River Boards Act, 1948, and the Rivers (Prevention of Pollution) Act, 1951.

The Public Health (Drainage of Trade Premises) Act, 1937 applies to England and Wales, with the exception of the administrative County of London and any area which before 1st July, 1937 drained into a sewer or sewage disposal works vested in the London County Council or a metropolitan borough council. Under the Act, in general, trade effluents can be discharged into public sewers only with the consent of the local authority given either conditionally or unconditionally, or in accordance with trade-effluent byelaws. There are certain important exceptions, however, to these conditions. The consent of the local authority is not necessary if a trade effluent of the same nature and composition was discharged lawfully from the premises into the sewer at some time during the year ended 3rd March, 1937, provided that the daily quantity discharged and the highest rate of discharge are not greater than during the year ended 3rd March, 1937.

By the River Boards Act, 1948, the Ministers were placed under an obligation to establish river boards, as soon as practicable, for areas together covering England and Wales, except the Thames and Lee catchment areas, and the administrative county of London and certain adjoining areas. Under the Rivers (Prevention of Pollution) Act, 1951 the duties of prevention of river pollution were in general transferred to the river boards, thereby reducing the number of authorities concerned with such functions. The Act is enforced by (*a*) river boards, (*b*) the Conservators of the River Thames, (*c*) the Lee Conservancy Catchment Board, and (*e*) metropolitan borough councils, and county or county borough councils for areas not otherwise covered. Under the Act, the river boards and equivalent authorities are empowered to make bye-laws prescribing standards of purity; and the consent of the boards must be obtained for the construction of new or altered outlets and for new discharges of trade effluents.

It is thus clear that industrial undertakings wishing to discharge effluents to sewers or to rivers, which may include tidal waters, must make arrangements with and satisfy the local sewage authority or the local river board or equivalent authority. The various authorities recognize that it is impracticable to render many trade effluents unpolluting in character, but they expect that all steps will be taken to keep down the amount of polluting matter discharged to the practicable minimum, taking all factors into account.

TECHNICAL PROBLEMS

During recent years, as a result of steady improvement in the methods of operation and control of the many processes in the iron and steel industry, and of new techniques based on systematic investigations in the laboratory and with pilot-scale and full-scale equipment, the pollution of air and water by discharges from the several branches of the industry has been greatly reduced, particularly in relation to the quantity of iron and steel produced. The great improvement in the general cleanliness of the works is obvious to anyone who has regularly visited works in different parts of the country over the last 30 or 35 years. There remain many difficult problems to be solved, however, if the considerable pollution that is still caused is to be further greatly reduced at reasonable cost. These problems are now generally recognized by those not engaged in the industry. For example, it is because of the difficulties in reducing the discharge of air pollutants that by the Alkali, Etc. Works Order, 1958, more of the processes with which the industry is concerned have been brought under the control of the Alkali Inspectorate instead of being left under the jurisdiction of the Public Health Act, 1936 and the Clean Air Act, 1956, which are administered by the local authorities. The Alkali Inspectors are technical experts who have achieved a high reputation as sympathetic advisers; they encourage investigations and assist in overcoming difficulties and take legal action only as a last resort when they are convinced that no real effort has been made to adopt the best practicable means.

Air Pollution

Every large works has plant for raising steam and for generating electricity for various power units. Many of these power stations are fired with blast-furnace gas, sometimes with the addition of coke-oven gas; as a standby there are usually facilities for firing boilers with coke breeze. Air pollution from these plants is ordinarily slight and there should be no difficulty in at least attaining the standards set by the regulations issued or likely to be issued under the Clean Air Act, 1956.

Substantial quantities of raw producer gas made from coal are used in making steel in open-hearth furnaces, though the amount is decreasing. At regular intervals it is necessary to burn out the carbonaceous tarry matter deposited in the gas mains and this causes the emission of dense clouds of black smoke. If the use of raw producer gas is to be continued it might be possible, at a price, to complete the combustion in a specially designed combustion chamber and thus to avoid smoke emission.

The duties of the locomotives in iron and steel works are similar to those of shunting engines on the railways. When these engines are fired with coal they often cause severe low-level pollution by smoke, particularly when they are lit up from a cold condition. Fortunately, coal-fired locomotives are steadily

being replaced by diesel-electric engines. Most of the coal-fired steam cranes have been replaced by electrically operated cranes.

One third of the coke-oven plants in the U.K. are owned by iron and steel companies and most of the coke made in the other coke ovens is also used in blast-furnaces. Smoke, grit, and dust are discharged to the air during charging and discharging the ovens and during the quenching and screening of the coke. These problems of air pollution from coke-oven installations have been investigated in detail but they have not been entirely solved. The use of double gas-collecting mains reduces smoke emission during the charging of coal into the ovens, but has certain operational disadvantages. Much can be done by careful maintenance of the plant, particularly the oven doors, to avoid unnecessary leakages by having well designed coke-quenching systems and by ventilating systems with grit arrestors on the coke-screening plant.

Dust is created in delivering iron ore to the stockyards and in removing it for use. Most of this dust is fairly coarse and settles within the works unless there are strong winds to carry it over longer distances. Much more dust arises from the preparation of the ore for the blast-furnace by crushing, drying, and screening, and especially from the process of converting the ore into sinter. Some of the dust is carried direct to the air and much of it is carried by the waste gases from the driers and from the sintering plant. By means of ventilating systems equipped with dust arrestors and by passing the dust-laden waste gases through efficient arrestors, great reductions in the quantity of dust finally discharged to the atmosphere have been achieved, but there is still room for considerable improvement at some works.

At modern works, the amount of air pollution from the operation of the blast-furnace is normally small, but occasionally an uncontrolled slip of the charge in the furnace may open the explosion doors at the top of the furnace; crude gas heavily charged with dust is then emitted to the atmosphere. Preparation of the ore by sintering has assisted towards the improvement of furnace operation and control and to a reduction in the frequency of uncontrolled slips.

The most difficult problems of mitigation of air pollution by the industry which have not been satisfactorily solved, taking costs into account, are those arising from the production of steel in open-hearth furnaces, electric-arc furnaces, and converters. Before the molten metal from the blast-furnace is charged to the steelmaking furnaces, some works pre-refine the metal by blowing oxygen or a mixture of oxygen and steam on to or into the metal. Copious red fumes are evolved. There have been experiments on methods of removing the fumes from the gases discharged but no full-scale plants have been installed.

Very large quantities of gas carrying dust and fume are discharged from open-hearth furnaces. At several works in the U.S.A. electrostatic precipitators, which are costly, have been used to clean the gas. In the U.K. there have been tests with pilot plant, but there are no full-scale installations. The electric-arc furnace is used mainly for the manufacture of stainless and other special steels, but when combined with refining by means of oxygen its use is increasing for other steels produced in larger quantity. The volume of gas discharged is relatively small but the gas carries large quantities of fume mainly in the form of very fine particles of iron oxide. Ventilating systems have been installed over some of these furnaces and the gas so collected has been cleaned by venturi scrubbers, electrostatic precipitators, or by bag filters.

The most difficult problem is that of cleaning the gas discharged from the bottom-blown converter. Difficulties arise partly because the converter has to be filled at various angles, and partly because during the blowing period flames extend to a distance of 10 ft or more from the mouth. Consequently, it is not easy to provide a ventilating hood for collecting the gas, which emerges at high velocity. Experiments on various methods of collecting and cleaning the gas have been carried out in several countries, but no satisfactory economic process has been fully developed.

In the treatment of steel by casting, rolling, reheating, and de-seaming, the serious discharge of polluting gases can be avoided by careful control of the operations, except in de-seaming by means of oxy-acetylene burners. Usually, de-seamers are ventilated by a system of hoods and ducts and the contaminated air is cleaned by passage through a mechanical dust collector.

Water Pollution

Most of the problems of disposal of polluting liquids from the iron and steel industry can be surmounted, if not entirely solved, by careful integration and control of the amounts and types of water required for the various processes, combined with treatment of the waste waters by such methods as sedimentation, flocculation, and filtration so that much of the water can be re-used. By these means the net demand for fresh water can be kept down to a reasonable amount, thereby leading to financial savings towards meeting the cost of treating the waters for re-use and easing the difficulties of disposal of effluent that has necessarily to be discharged. The methods most suitable vary in detail with the works and the local conditions.

The disposal of spent pickle liquor has long been a problem at many works. In some instances, the problem has been eased by methods of recovering acid in a form suitable for re-use in pickling the metal, or a saleable by-product has been obtained. But at most works, some, if not all, of the spent liquor has had to be neutralized before disposal.

One major problem that has not been solved at reasonable cost is that of disposal of spent ammoniacal liquor from coke-oven installations. This problem is common to both the coking and the gas industries and it has been the subject of almost continuous investigation for at least half a century. Of the methods proposed and adopted, the least costly is to mix the effluent with town sewage for treatment at the local sewage treatment works, but difficulties arise at the sewage works if the quantity of spent liquor exceeds about 0·5% of the dry-weather flow of sewage. Coke-oven installations are now so large that the quantity of spent ammoniacal liquor usually

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It is thus clear that industrial undertakings wishing to discharge effluents to sewers or to rivers, which may include tidal waters, must make arrangements with and satisfy the local sewage authority or the local river board or equivalent authority. The various authorities recognize that it is impracticable to render many trade effluents unpolluting in character, but they expect that all steps will be taken to keep down the amount of polluting matter discharged to the practicable minimum, taking all factors into account.

TECHNICAL PROBLEMS

During recent years, as a result of steady improvement in the methods of operation and control of the many processes in the iron and steel industry, and of new techniques based on systematic investigations in the laboratory and with pilot-scale and full-scale equipment, the pollution of air and water by discharges from the several branches of the industry has been greatly reduced, particularly in relation to the quantity of iron and steel produced. The great improvement in the general cleanliness of the works is obvious to anyone who has regularly visited works in different parts of the country over the last 30 or 35 years. There remain many difficult problems to be solved, however, if the considerable pollution that is still caused is to be further greatly reduced at reasonable cost. These problems are now generally recognized by those not engaged in the industry. For example, it is because of the difficulties in reducing the discharge of air pollutants that by the Alkali, Etc. Works Order, 1958, more of the processes with which the industry is concerned have been brought under the control of the Alkali Inspectorate instead of being left under the jurisdiction of the Public Health Act, 1936 and the Clean Air Act, 1956, which are administered by the local authorities. The Alkali Inspectors are technical experts who have achieved a high reputation as sympathetic advisers; they encourage investigations and assist in overcoming difficulties and take legal action only as a last resort when they are convinced that no real effort has been made to adopt the best practicable means.

Air Pollution

Every large works has plant for raising steam and for generating electricity for various power units. Many of these power stations are fired with blast-furnace gas, sometimes with the addition of coke-oven gas; as a standby there are usually facilities for firing boilers with coke breeze. Air pollution from these plants is ordinarily slight and there should be no difficulty in at least attaining the standards set by the regulations issued or likely to be issued under the Clean Air Act, 1956.

Substantial quantities of raw producer gas made from coal are used in making steel in open-hearth furnaces, though the amount is decreasing. At regular intervals it is necessary to burn out the carbonaceous tarry matter deposited in the gas mains and this causes the emission of dense clouds of black smoke. If the use of raw producer gas is to be continued it might be possible, at a price, to complete the combustion in a specially designed combustion chamber and thus to avoid smoke emission.

The duties of the locomotives in iron and steel works are similar to those of shunting engines on the railways. When these engines are fired with coal they often cause severe low-level pollution by smoke, particularly when they are lit up from a cold condition. Fortunately, coal-fired locomotives are steadily

being replaced by diesel-electric engines. Most of the coal-fired steam cranes have been replaced by electrically operated cranes.

One third of the coke-oven plants in the U.K. are owned by iron and steel companies and most of the coke made in the other coke ovens is also used in blast-furnaces. Smoke, grit, and dust are discharged to the air during charging and discharging the ovens and during the quenching and screening of the coke. These problems of air pollution from coke-oven installations have been investigated in detail but they have not been entirely solved. The use of double gas-collecting mains reduces smoke emission during the charging of coal into the ovens, but has certain operational disadvantages. Much can be done by careful maintenance of the plant, particularly the oven doors, to avoid unnecessary leakages by having well designed coke-quenching systems and by ventilating systems with grit arrestors on the coke-screening plant.

Dust is created in delivering iron ore to the stockyards and in removing it for use. Most of this dust is fairly coarse and settles within the works unless there are strong winds to carry it over longer distances. Much more dust arises from the preparation of the ore for the blast-furnace by crushing, drying, and screening, and especially from the process of converting the ore into sinter. Some of the dust is carried direct to the air and much of it is carried by the waste gases from the driers and from the sintering plant. By means of ventilating systems equipped with dust arrestors and by passing the dust-laden waste gases through efficient arrestors, great reductions in the quantity of dust finally discharged to the atmosphere have been achieved, but there is still room for considerable improvement at some works.

At modern works, the amount of air pollution from the operation of the blast-furnace is normally small, but occasionally an uncontrolled slip of the charge in the furnace may open the explosion doors at the top of the furnace; crude gas heavily charged with dust is then emitted to the atmosphere. Preparation of the ore by sintering has assisted towards the improvement of furnace operation and control and to a reduction in the frequency of uncontrolled slips.

The most difficult problems of mitigation of air pollution by the industry which have not been satisfactorily solved, taking costs into account, are those arising from the production of steel in open-hearth furnaces, electric-arc furnaces, and converters. Before the molten metal from the blast-furnace is charged to the steelmaking furnaces, some works pre-refine the metal by blowing oxygen or a mixture of oxygen and steam on to or into the metal. Copious red fumes are evolved. There have been experiments on methods of removing the fumes from the gases discharged but no full-scale plants have been installed.

Very large quantities of gas carrying dust and fume are discharged from open-hearth furnaces. At several works in the U.S.A. electrostatic precipitators, which are costly, have been used to clean the gas. In the U.K. there have been tests with pilot plant, but there are no full-scale installations. The electric-arc furnace is used mainly for the manufacture of stainless and other special steels, but when combined with refining by means of oxygen its use is increasing for other steels produced in larger quantity. The volume of gas discharged is relatively small but the gas carries large quantities of fume mainly in the form of very fine particles of iron oxide. Ventilating systems have been installed over some of these furnaces and the gas so collected has been cleaned by venturi scrubbers, electrostatic precipitators, or by bag filters.

The most difficult problem is that of cleaning the gas discharged from the bottom-blown converter. Difficulties arise partly because the converter has to be filled at various angles, and partly because during the blowing period flames extend to a distance of 10 ft or more from the mouth. Consequently, it is not easy to provide a ventilating hood for collecting the gas, which emerges at high velocity. Experiments on various methods of collecting and cleaning the gas have been carried out in several countries, but no satisfactory economic process has been fully developed.

In the treatment of steel by casting, rolling, reheating, and de-seaming, the serious discharge of polluting gases can be avoided by careful control of the operations, except in de-seaming by means of oxy-acetylene burners. Usually, de-seamers are ventilated by a system of hoods and ducts and the contaminated air is cleaned by passage through a mechanical dust collector.

Water Pollution

Most of the problems of disposal of polluting liquids from the iron and steel industry can be surmounted, if not entirely solved, by careful integration and control of the amounts and types of water required for the various processes, combined with treatment of the waste waters by such methods as sedimentation, flocculation, and filtration so that much of the water can be re-used. By these means the net demand for fresh water can be kept down to a reasonable amount, thereby leading to financial savings towards meeting the cost of treating the waters for re-use and easing the difficulties of disposal of effluent that has necessarily to be discharged. The methods most suitable vary in detail with the works and the local conditions.

The disposal of spent pickle liquor has long been a problem at many works. In some instances, the problem has been eased by methods of recovering acid in a form suitable for re-use in pickling the metal, or a saleable by-product has been obtained. But at most works, some, if not all, of the spent liquor has had to be neutralized before disposal.

One major problem that has not been solved at reasonable cost is that of disposal of spent ammoniacal liquor from coke-oven installations. This problem is common to both the coking and the gas industries and it has been the subject of almost continuous investigation for at least half a century. Of the methods proposed and adopted, the least costly is to mix the effluent with town sewage for treatment at the local sewage treatment works, but difficulties arise at the sewage works if the quantity of spent liquor exceeds about 0·5% of the dry-weather flow of sewage. Coke-oven installations are now so large that the quantity of spent ammoniacal liquor usually

greatly exceeds 0·5% of the flow of sewage to the local treatment works. Other methods of treatment of the liquor for ultimate disposal must therefore be adopted. These include biological oxidation under carefully controlled conditions at the coke works, either in percolating filters or by the activated-sludge process (or by both systems), or absorption by ion-exchange resins and active carbon. These methods are all very costly, but often there is no alternative.

The first aim should always be to operate the coke ovens and ancillary plant as to ensure that the volumes of ammoniacal liquor and spent liquor are kept as small as possible. There should also be early separation of tar and liquor. If the amount of monohydric phenol in the liquor is 0·3% or more, it may be profitable to recover the phenol by one of the solvent processes available and at the same time reduce the polluting character of the effluent for disposal.

CONCLUSION

It is certain that in our highly industrialized and thickly populated country, no industry will be allowed in the future to continue unnecessarily causing severe pollution of air and of water resources. Public opinion is demanding improvement, and legislation with the same object has been greatly strengthened during the last few years. Another important factor is that when labour is in demand, those works and factories that are clean and attractive in appearance have less difficulty in recruiting the better employees than those that are untidy and enveloped in unpleasant gases, vapours, grit, and dust.

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Consequently much attention has been paid to the development of electrolytic processes for making iron powder. Some of these are refining methods, i.e. more or less crude iron is electrolytically refined, while others are production methods which start from ore or scrap that is dissolved, forming solutions which are then electrolysed using insoluble anodes. It appears that the refining methods have been more successful for the production of powder, probably because it is difficult to combine the most favourable conditions for electrolysis with the conditions required for the other stages of a production method, e.g. the leaching of ore or scrap.[1]

When Husqvarna Vapenfabriks AB decided more than 10 years ago to start the production of sintered machine parts in Sweden, it was quite clear that the requirements in respect of quality could not be met with the iron powders then on the market. The same trend was to be found in the U.S.A., where the Tacoma plant and the Buel plant in Plainsville, Ohio, were started about that time.[2]

Metal powders can be produced electrolytically in two different ways: the direct precipitation of powder on the cathode, and the deposition of a brittle product which can subsequently be ground to powder. The choice between the two methods depends on the electrochemical characteristics of the metal, i.e. the relation of cathode potential to current density. For metals of low chemical polarization, e.g. Ag, Pb, Cu, Zn, and Cd, it is natural to use the direct deposition of powder. Most of these metals are also rather soft and consequently difficult to grind.[3] The metals of the iron group (Fe, Ni, and Co) have high chemical polarization and can therefore easily be deposited under conditions favourable to the formation of brittle deposits which are easy to grind.

To obtain a suitable and uniform grain-size distribution in the powder, factors such as current density, temperature, acidity, and ion-concentration in the solution must be controlled within narrow limits in direct deposition. The powder deposited must be scraped off the cathode at intervals to avoid

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Consequently much attention has been paid to the development of electrolytic processes for making iron powder. Some of these are refining methods, i.e. more or less crude iron is electrolytically refined, while others are production methods which start from ore or scrap that is dissolved, forming solutions which are then electrolysed using insoluble anodes. It appears that the refining methods have been more successful for the production of powder, probably because it is difficult to combine the most favourable conditions for electrolysis with the conditions required for the other stages of a production method, e.g. the leaching of ore or scrap.[1]

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a decrease in current density which would lead to coarser grains.

When indirect methods can be applied they offer some advantages, The cathode deposit can be allowed to grow into fairly thick layers without too great a decrease in 'grindability.' The greatest advantage, however, from the powder-metallurgical viewpoint is that by varying the milling and reduction processes, a wide variety of qualities of powder can be obtained. The grain shape can also be controlled to meet the requirements in respect of apparent density, flow, and green strength.

The present method used at Husqvarna can be described as a refining method for the production of iron powder by the indirect method. Investigations on both a laboratory and a pilot-plant scale have shown that an acid chloride solution offers the greatest advantages in the process.[4]

Sulphate solutions are not so corrosive as chloride solutions, though with the modern constructional materials for pumps, tubes, etc., this is no longer a factor of great importance. They have, however, a lower conductivity and can cause passivation of the anodes, at least at lower temperatures. Since traces of salt may be deposited with the metal there may be a certain sulphur content in the powder, but for most powder-metallurgical purposes this sulphur will not cause any trouble.

The brittleness of electrolytically deposited iron may arise in various ways. In iron obtained from pure, relatively acid solutions, the hardness is due mainly to absorbed hydrogen. Such a deposit can be ground, but the product consists chiefly of needle-like grains which give the powder excellent green strength but poor flow characteristics.

In iron deposited from slightly acid or nearly neutral solutions, the hardness is due to the presence of submicroscopic colloidal iron hydroxide. This precipitated hydroxide also disturbs the crystallization process. Other particles suspended in the solution, both conducting and non-conducting, tend to disturb the electrocrystallization of metals.[5] Iron deposited under conditions favouring the precipitation of hydroxide can be ground easily to give a powder having excellent properties. The content of precipitated hydroxides or other substances must, however, be closely controlled, as it may be difficult to reduce the oxygen content of the powder to the level required for good compressibility.

Production at Husqvarna starts with the preparation of anode plates from scrap. The cathodes are made of stainless steel and the solution is made up from ferrous chloride. The conductivity of ferrous chloride is low and therefore some ammonium chloride is added as a conducting salt. With a current density of 3–6 A/dm^2, the cathodes remain in the vat for 2–3 days, then they are taken out and stripped. The deposit is carefully washed and dried. The milling of the deposit is carried out in a system of ball-mills working in a closed circuit. Sieving is carried out in an air classifier. The reduction is effected in pusher-type furnaces. After reduction, the powder is reground in hammer-type mills and control-sieved. The whole process is so regulated that a good grain-size distribution is obtained directly.

Table I

PHYSICAL PROPERTIES OF FOUR GRADES OF IRON POWDER OBTAINED WITH MPA TEST-BARS PRODUCED AS SHOWN

Pressing 43 tons/in^2 Repressing 43 tons/in^2
Sintering 1 h at 850° C Resintering 2 h at 1250° C

	HVA Star	HVA Standard	Reduced	Atomized
Apparent Density, g/cm^3	2·6–2·8	3·4–3·6	2·5	2
Pressed Density (43 tons/in^2)	7·0	7·2	6·7	6·7
Tensile Strength × 1000, lb/in^2	38·0 (7·4 g/cm^3)	37·0 (7·4 g/cm^3)	28·0 (7·1 g/cm^3)	36·0 (7·2 g/cm^3)
Elongation, %	34	24	17	15

Table I shows the properties of the two qualities of iron powder which are now produced by Husqvarna Vapenfabriks. For comparison, properties of two other commercial iron powders are included.

The flexibility of the HVA method makes it possible to produce powders with a range of grain-sizes and grain structures, from dense, coarse grains giving an apparent density of about 4 g/cm^3 to spongy, porous grains of apparent density about 2 g/cm^3.

Fused-salt Electrolysis

In fused-salt baths the deposit is always obtained in a pulverulent state when the temperature of the bath is below the melting point of the metal. The refining of iron in molten-salt baths has been studied to investigate the problems involved in the cleaning of the powder product. The main purpose of the work carried out at Husqvarna was, however, to investigate the production of iron powder from consumable electrodes made up from iron ore, coal, and coke. The iron is deposited as powder on the cathode and is scraped off and collected in a basket on the bottom of the electrolysis vat. When the basket is taken out, the iron powder is found to be mixed with about an equal amount of salt. This mixture is soaked in water. It is, however, very difficult to get rid of all the salt, and the powder therefore tends to rust more than powders deposited from aqueous solutions.

The iron powder electrolysed from molten-salt baths is well crystallized in the form of cubes or 'picture frames,' very often forming fairly long lines of crystals. The grain-size can be controlled comparatively easily, and the compressibility, green strength, and sintering activity of the powder are excellent. However, owing to the high production costs as well as the difficulties involved in obtaining a completely salt-free powder, this method cannot compete with electrolysis from aqueous solutions.

The investigations with consumable electrodes revealed a further difficulty as the electrodes tended to crack and the powder obtained was therefore contaminated with material from the anode.

Alkaline Solutions

A very interesting method for the production of pure electrolytic iron powder from an alkaline solution has been proposed by Professor Angel, of the Royal Technical Institute, Stockholm. The back-

ground to this process is as follows. A Swedish engineer, Mr. Estelle, many years ago developed a method for the production of electrolytic iron from spent pickling solutions. The iron was precipitated as ferrous hydrate, which was dissolved in strong alkaline solutions to form 'sodium ferrite.' When this was electrolysed between iron cathodes and nickel anodes, the iron obtained was very pure.

Professor Angel's idea was to start from other oxide substances, as for instance iron-ore concentrate, which is readily available and comparatively cheap in Sweden. Two principal methods can be used. One is to carry out the process in two stages, namely, the conversion of the iron ore (Fe_3O_4) into 'sodium ferrite' and the electrolysing of this solution. The other is to effect the dissolution and the electrolysis in the same step. This second way is, of course, the more attractive, but it presents some complex problems. The solubility of iron in alkaline solutions is very low. In order to maintain the current efficiency at a high level, this low concentration must be maintained and therefore the rate of solution of the iron-ore concentrate is the controlling factor. Many attempts have been made to raise the rate of solution, as for instance by grinding to a very fine particle size, supersonic treatment of the dispersion in the electrolysis vat, and chemical treatment of the ore concentrate. These attempts have not yet been successful, but further investigations will be made along new lines.

Investigations made into the two-stage method have been comparatively successful, giving a fairly high current efficiency over a long period. The iron obtained is of good quality. A very interesting feature of the process is that the iron has good resistance to rusting compared with iron made from acid solutions.

Amalgam-metallurgical Preparations

The amalgam-metallurgical preparation of metal powders presents some interesting aspects. Although the solubility of iron and nickel in mercury is very low (0·00002 and 0·00005 mole/l. respectively), it is possible to 'deposit' them on a mercury cathode because the iron is dispersed in the mercury phase. As the potential conditions can be very closely controlled, it is possible to obtain a high-purity iron. The method seems to be well suited to the production of electrolytic iron from spent pickling solutions. A rather low concentration of iron dispersed in mercury is obtained, as the current efficiency drops rapidly at concentrations above 1% iron, and consequently the separation of iron from mercury is important. By squeezing the dispersion, separating the iron under slightly oxidizing conditions, and finally reducing it with hydrogen at a low temperature, a pure iron powder with extremely small particle size can be obtained.[8] The size of the primary grains is found to be about 50 mμ. Because of its high purity, this iron powder will be of interest for magnetic purposes. The grain-size seems to be somewhat larger than is needed for permanent magnets of the Néel type, but the high purity and the sintering activity make it well suited for the sintering of magnets and soft magnetic alloys. However, the very poor flow characteristics of the powder make it unsuitable for general powder-metallurgical purposes.

NICKEL POWDER

Most of the methods used for the production of iron powder can also be used for the production of nickel powder. The best way seems to be to produce brittle deposits from acid sulphate solutions, which are milled to powder.[7] A fine-grained powder can be made by the amalgam-metallurgical method.

FERRO-ALLOYS

Aqueous Solutions

The excellent properties of electrolytic iron powder prompted HVA to investigate the possibilities of producing iron alloys electrolytically. Special attention was paid to Fe–Ni, Fe–Mn, Fe–Mo, and Fe–Cr alloys.

To deposit an alloy of two metals on the cathode, the electrolytic conditions must be adjusted in such a way that the two metals will have the same deposition potential. Therefore the concentration of the different metals in the solution must be kept under close control, as well as the anodic and cathodic reactions. The following principal types of anodes can be used:

(i) Anodes of a soluble alloy
(ii) Soluble anodes of each metal
(iii) Insoluble anodes; in this case the salts of the metals to be deposited have to be added continuously to the solution
(iv) A combination of (i) and (ii) or (i) and (iii).

Type (i) seems to be the most simple, but several factors such as the physical and chemical properties of the anodes have a great influence on the behaviour of the solution.

The use of soluble anodes of each metal offers the possibility of controlling the amount of metal dissolved by regulating the current passing through each anode. This method was chosen for the production of nickel–iron alloys. The object was to prepare alloys with 4–8, 20, and 80% nickel in a brittle condition, suitable for milling to powder.[9] It was shown that these alloys could be produced. A low current density favoured the deposition of a nickel-rich phase, while a high current density gave rise to an iron-rich phase. At points of the cathodes where the current density is locally increased, a phase richer in iron is deposited, while the spaces between are filled with a nickel-rich phase. It has been observed by Wranglén that the outermost points of the deposits, where the current density was high, consisted of the iron-rich phase.[9] Wranglén has made microscopic and X-ray investigations on the deposited alloys and found that they consisted of supersaturated solid solutions.

It proved difficult to obtain alloys containing between 20 and 80% nickel. In some cases alloys with an average nickel content of 50–60% were made, but it was found later that they consisted of separate layers of the two phases. The alloys were brittle and could be ball-milled to powder. The 4–8% nickel alloy was tested in the production of sintered Cu–Ni steel, to investigate whether this alloy would give better properties than a mixture of nickel and iron powders. Table II shows the results obtained.

Arbstedt[10] made some investigations into the

Table II

PHYSICAL PROPERTIES OF Ni AND Ni–Cu-ALLOY SINTERED STEELS PREPARED AS SHOWN

Pressing 43 tons/in² Repressing 57 tons/in²
Sintering 1 h at 1250° C Resintering 2 h at 1250° C

Alloy	Density, g/cm³	U.T.S. × 1000 lb/in²	Elongation, %
4% Ni	7·7	57·0	27
8% Ni	7·7	52·0	20·0
8% Ni + 2% Cu	7·6	70·0	10·0

electrolytic production of Fe–Mn alloys, and found that brittle deposits could be obtained containing up to about 20% Mn. Measurement of the cathode potentials showed that iron and manganese were deposited simultaneously, thus forming a solid solution. This was confirmed by X-ray investigations.

Fe–Mo alloys seem to be more difficult to deposit. The solutions needed are comparatively complex and the current efficiency is low. As the oxides of molybdenum are easily reduced by hydrogen, and molybdenum can therefore be added to iron powder without any difficulty, these investigations were not carried further than the laboratory stage. The alloys obtained were brittle and gave equiaxial grains after ball-milling.[11]

Alloys of iron and chromium have for long been of special interest to powder metallurgists because of the possibility they offer of achieving higher physical properties as well as of making stainless-steel parts. As the production of high-strength steel was of greatest interest, the aim was to produce an alloy containing 10% Cr. Several different types of solutions were investigated, but it was not possible to find a practical economical method of producing oxide-free brittle deposits from aqueous solutions.[12]

Fused-salt Electrolysis

Electrolysis in fused-salt baths is generally more difficult and expensive than that in aqueous solutions. In some cases, however, this method can offer some advantages. Metals which, because of their electrochemical characteristics, cannot be deposited from aqueous solutions, can be electrolytically deposited in the form of powder from molten-salt baths. As the metals are deposited in a soft state, it is difficult to mill them to a suitable grain-size, and consequently the current density and the concentration of the ions of the metal to be deposited must be controlled within close limits.

When salts of sodium or potassium are used, it is also necessary to avoid the formation of metallic sodium or potassium, as these will reduce oxides or compounds of more noble metals, forming very fine grains. Later on, during the leaching of the powder–salt mixture (as mentioned above), these fine grains may be easily oxidized. Therefore the concentration of the metal or metals to be deposited must not be lowered to such an extent as to allow the alkali metals to be reduced from the bath.

Investigations carried out at Husqvarna Vapenfabriks[13] have shown that it is possible to produce alloys containing 3·5%Ni, 1%Cr, and the rest Fe, and 18%Cr, 8%Ni, the rest Fe, in a grain-size distribution which can be used for powder-metallurgy purposes. Table III shows properties of powders obtained.

Table III

CHARACTERISTICS OF ALLOY POWDERS DEPOSITED FROM FUSED-SALT BATHS

Alloy	Flow	Apparent Density, g/cm³	Sieve Analysis Mesh					Pressed Density (27 tons/in²), g/cm³
			>65	>100	>200	>270	<270	
3·3% Ni, 0·8% Cr	42	1·7	28	21	21	22	8	6·2
7·3% Ni, 14·5% Cr	48	1·6	1	4	7	20	68	5·1

Test-pieces made from the 18–8 quality steel showed fairly good resistance to corrosion, in spite of their comparatively low density. X-ray and structural analyses showed that the iron, nickel, and chromium were alloyed to a certain extent. It was, however, obvious that the 18–8 steel contained chromium oxide. In particular the sub-sieve grains were found to be oxidized.

Before the fused-salt electrolytic method can be used for the commercial production of alloys with a high content of chromium, more development work must be carried out on both the electrolysis process itself and the design of the apparatus.

Among the above-mentioned electrolytic powders, only iron powder seems to be of importance for the production of sintered parts. The reason for this appears to be that the other metals or alloys can be made more cheaply and of equal quality by other methods, for instance by atomizing or the use of the carbonyl method or modern hydrometallurgical processes.

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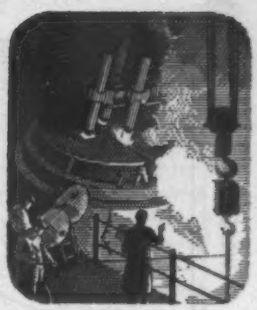

Large Electric-arc Furnace Steelmaking Experience in the U.S.A.

By A. C. Ogan and D. J. Carney

SYNOPSIS

This paper presents some current operating data and thinking in the U.S.A. in regard to the use of the electric furnace for production of plain carbon-steel ingots. The first section deals with trends in furnace design and equipment, particularly emphasizing the marked trend towards large steelmaking furnaces since World War II. Other structural changes are also mentioned. The second section deals with present practices in the U.S.A. for production of plain carbon ingots, including the use of hot metal. The third section lists a summary of the latest operating statistics from large U.S. furnaces producing solely plain carbon ingots. These data indicate a marked improvement in the past four years. The last section discusses in a general manner the economics of electric furnaces versus open-hearth furnaces for production of plain carbon ingots. 1541

THE INSTALLATION of a 4-ton electric-arc furnace in Syracuse, New York, in 1906 was the U.S.A.'s introduction to a new method of steelmaking. By 1910, nine more electric furnaces had been installed, making a total of ten furnaces, which produced 58,350 tons of steel in that year, about 0·3% of the U.S. total. A steady growth, markedly accentuated in World War II, resulted in over 200 active steelmaking electric furnaces by 1956, with a capacity of 11·5 million ingot tons, about 8% of the U.S. total rated steel capacity. Figure 1 shows how electric-furnace production has risen in the U.S.A. from 1925 to 1957.

Early electric-arc furnace production was limited largely to high-quality steels such as certain alloy steels, tool steels, and stainless steels. The electric furnace was, and still is, the only type of furnace in which these steels could be successfully produced. Until quite recently, the increased demand for these grades was the major cause of the expansion of electric furnaces in the U.S.A. During the last world war, with the need for considerable tonnage of armament steels of electric-furnace grade and quality, a number of new large electric furnaces were constructed. However, the demand for carbon and open-hearth alloy steels also exceeded the supply at that time and electric furnaces were installed by non-integrated steel companies to provide their own supply of plain carbon-steel ingots. The favourable experience reported by some of these companies led some of the larger integrated steel producers to produce carbon steel in electric furnaces when alloy and stainless demand decreased. In the past five years, at least six large electric-furnace shops in the U.S.A. have devoted the major share of their total production to the plain carbon ingots in direct competition with open-hearth products. Because of this increasing trend in the U.S.A., numerous recent papers and studies have been made concerning the possibility of future electric-furnace expansion for plain carbon ingots.[1–10]

This paper will discuss the following factors as they relate to considerations in the U.S.A. of the production of plain carbon ingots in large electric furnaces:

(i) Recent trends in furnace design and equipment
(ii) Current operating practices for carbon-steel ingots
(iii) Use of large furnace for alloy and stainless steels
(iv) Current electric furnace operating data
(v) Comparison of the economics of large electric furnaces and open-hearth furnaces in the U.S.A.

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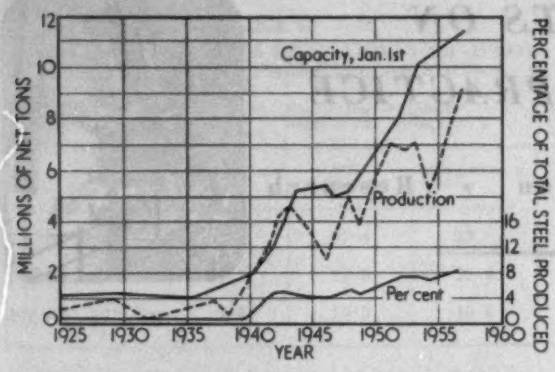

Fig. 1—Steel (for ingots and castings) produced in electric-arc furnaces in the U.S.A.—capacity, production, and percentage of total (*from Watkins Cyclopedia of the Steel Industry*,[9] p. 140)

MODERN TRENDS IN FURNACE DESIGN AND EQUIPMENT

Furnace Design

In the early years of development in the U.S.A. the size of electric furnaces grew slowly, but they did increase rapidly in numbers. Although top charging of smaller furnaces was known in 1925, it was not until 1932 that top charging became accepted by the industry and the trend toward the use of larger furnaces actually started. Figure 2 indicates the maximum-size furnaces that existed in the U.S.A. from 1932 to date. As can be seen, the maximum-size door-charged furnace has been the same over the last 35 years. A door-charged 100-ton six-electrode furnace was installed in 1927; it is the only one of its kind in the U.S.A. and, to the authors' knowledge, in the world. It has remained the largest door-charged furnace because emphasis was placed on increasing furnace size for top-charged furnaces. Because of the increase in production rates resulting from top charging and the earlier experience with carbon steels, the number of large furnace installations has tripled since 1945. In a few instances large electric-furnace installations were made to replace cold-charged open-hearth furnaces. This trend in both number and size of electric-furnace installations is shown in Table I. The maximum size for electric furnaces has not yet been determined. It appears that the size of the door-charged furnace has reached

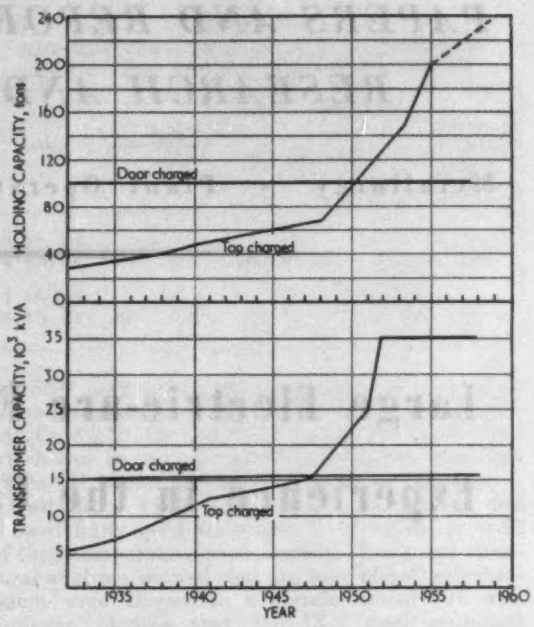

Fig. 2—Largest electric-arc furnace and largest furnace transformer installations in the U.S.A. since 1932 (*A.I.M.M.E. Electric Furn. Steel Conf. Proc.*, 1953)

its limit, unless potential hot-metal usage in the future should reveal a possible cost advantage that might make a larger door-charged furnace with greater hearth area and less bath depth practical. Top-charged furnaces, on the other hand, still continue to increase in size. Installations of 100-ton, 150-ton, and 200-ton furnaces were made in 1950, 1953, and 1954 respectively, and the American Bridge Division of the United States Steel Corporation has recently designed a 250-ton elliptical six-electrode furnace. In the U.S.A. future installations will no doubt continue to be larger top-charged furnaces of the tilting type, although this will require improvement in tilting mechanisms.

In order to make the sharp advancements in furnace size, many improvements in design and construction have been developed over the years. Heavier structural members with all-welded construction and the cage-type shell developed by the

Table I

STEEL INGOT* PRODUCING ELECTRIC-ARC FURNACES, 1910–1957

Year	Furnace Capacity, tons												Total Furnaces	Total Annual Capacity, tons
	Not Described	0–1·0	1·1–5·0	5·1–10·0	10·1–15·0	15·1–20·0	20·1–30·0	30·1–40·0	40·1–50·0	50·1–70	70–110	150	200	
	No. of Furnaces													
1910	2		3	1	3								9	52,000
1920	1	74	130	104	7	1	4	2					322	570,000
1930		14	45	55	7	1	7	2			1		132	930,000
1940	5	20	54	63	24	4	5	15	3	13	1		207	2,600,000
1950	4	6	29	42	26	16	16	16	12	44	2		213	7,500,000
1957	7		26	47	34	18	22	9	15	38	27	2	247	11,500,000

* Figures before 1930 include electric furnaces used for production of castings as well as ingots.[11–17] (Extracted from published data; does not include crucible process production.)

American Bridge Division have contributed to this advancement. New and improved tilting mechanisms, hydraulic or motor-operated doors, more rigid roof rings, and stronger and better-designed electrode masts have all aided in making large furnace installations practical and with only reasonable maintenance required.

Increase in Transformer Capacity

Transformers have increased in capacity at approximately the same rate as furnace size. Figure 2 shows the changes in transformer sizes from 1932 to date, and Fig. 3 describes the normal transformer requirements for various sizes of furnace. In the very early years the transformer capacity limits were dictated by the amount of power available. About 1920, with almost unlimited availability of power, other items became the limiting factors for determining transformer size. The size of electrodes and their current-carrying capacity were restrictive until improved electrode-manufacturing techniques were developed to overcome these deficiencies. Transformer cooling limited the current-carrying capacity of transformers until external cooling by heat exchangers was added. A new type of oil pump developed by the General Electric Company helped to make this possible. Today the limiting factor appears to be furnace refractories plus the inefficiency in melting scrap in large furnaces with one centralized heat source. This suggests a return to the six-electrode furnace in order better to distribute the source of the melting energy. As mentioned earlier, a 250-ton six-electrode furnace has been designed with this thought in mind. It is to be powered by two 30,000-kVA transformers, which should not only improve melting speed but should also lessen refractory damage from the long high-voltage arc. Present-day refractories are limiting transformers to about 35,000 kVA in the U.S.A.

Regulator Control

The high cost of power and electrodes required by electric furnaces has stimulated an intensive effort by all electric-furnace operators toward the reduction of these costs. In the past 15 years, great strides have been made by controlling the arc in the furnace through electrode positioning. From the early contact-making ammeter types of regulator, which utilized only one parameter of the arc power, and the subsequent balanced-beam type of contacting regulator, which utilized both arc power parameters, was evolved the rotating differential-type amplifier, which is the most popular today. This type of regulator amplifies the combined voltage and current signals from the arc through a special motor generator which furnishes an excitation proportional to the error signal to the electrode-positioning motor. The anticipating nature of this type of control and its greater sensitivity compared with previous controls has made possible electrode speeds of 120 in./min, where only 40 in./min were previously possible. This increased control efficiency has decreased power and electrode consumption, reduced heat times, and made possible the utilization of a higher power factor in furnace operation. Indications are that even better

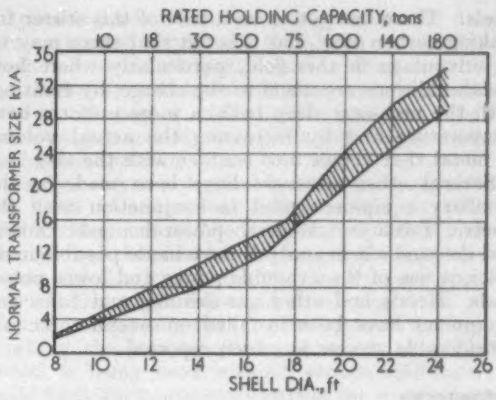
RATED HOLDING CAPACITY, tons
10 18 30 50 75 100 140 180
NORMAL TRANSFORMER SIZE, kVA
36 32 28 24 20 16 12 8 4 0
8 10 12 14 16 18 20 22 24 26
SHELL DIA., ft

Fig. 3—Electric-arc furnace inside shell diameter, rated holding capacity, and normal transformer size (*Watkins Cyclopedia of the Steel Industry*,[9] p. 145)

controls will be forthcoming to increase production rates and reduce operating costs still further. The optimum in arc control and electrode speed has not been reached. One of the large delay items in electric-furnace operation in the past has been slow-speed electrodes which must be lowered and raised many times in the course of a heat of steel.

Air Circuit Breaker, Remote-controlled Electrode Holder, and Other Auxiliary Furnace Equipment

The main interrupting device for power on the furnace transformer is the circuit breaker, which may be of the oil or air-blast type. Almost all large furnaces are now using the air-blast type in place of the oil type, principally because of the reduced maintenance time required to keep the circuit breaker operating safely. The older oil type had most of its parts submerged in oil, and so, to change a worn switch blade, the whole unit had to be drained; it also had to have a complete change of oil about every 4000 trips because of its inherent character of building up the free carbon content, thus reducing its arc-quenching effect. Such maintenance often required up to 4-h loss of operating time; air-blast circuit breakers, on the other hand, are quite simply maintained and repaired.

The most popular advance in furnace auxiliary equipment, at least as far as the furnace crews are concerned, has been the remote-controlled electrode holder. These electric or air-powered holders are rapidly replacing the manually operated wedge- or screw-type holders in the U.S.A. Remote-controlled holders eliminate the need for the furnace crew to go on top of the furnace roof while trying to adjust a wedge or screw which had been set too tight. The improvements realized by this device have been improved safety of operation, decreased electrode-changing and positioning time, reduced maintenance on electrode holders, and, through better contact, reduced electrode consumption and power consumption.

Two recent electric-furnace installations in the U.S.A. have incorporated induction stirrers. The shops with these installations have claimed some advantages in improved quality of alloy and stainless

steels. There has yet to be a trial of this stirrer for making carbon steel, but it is felt that there may be an advantage in this field, particularly where hot-metal additions are made to the charge, by creating, with the necessary deep bath, a more uniform bath temperature and by increasing the actual volume of metal that comes into contact with the slag.

Several other advances have been made in the auxiliary equipment used in conjunction with the electric furnaces. Modern power-demand limiters and demand alarm controls have made possible more efficient use of the available power and lower power costs. Hoods and other gas-cleaning and collecting equipment have been installed on several units, and considerable success has been reported.

Refractories

Although development in electric-furnace refractories has progressed at a slower rate than desired by most operators in the U.S.A., there have been some improvements in recent years which are worthy of mention.

All carbon and alloy ingot-producing electric-furnace shops in the U.S.A. use basic refractories, except for the roofs, and some are now experimenting with partial and complete basic roofs. High-magnesia (90%) brick has been developed for sub-hearth construction, and improved metal-clad brick for the side walls have made improvements in refractory costs in many shops. The newer fused chrome-magnesite brick that has been melted in an electric furnace and cast into moulds and cut to shape has been used recently to minimize sidewall erosion, which results from the higher-powered transformers and longer arcs. These bricks, however, are expensive and must be used locally in panels in the furnace hot-spots if the proper balance of costs is to be realized.

Higher-magnesia ramming materials that are chemically bonded have improved bottom and bank conditions in some shops.

As mentioned earlier, basic roofs, both as entire roofs and as partial roofs, have been tried; to date, insufficient data are available to discuss relative merits. The use of high-alumina roof brick and ramming or castable material of the same composition has made cost reductions in roof maintenance for some operators.

Even with these improvements in refractories, it now appears that furnace refractories are the limiting factor in furnace size and transformer capacities, unless there is a return to the six-electrode furnace.

OPERATING PRACTICE FOR MAKING CARBON STEEL IN LARGE ELECTRIC-ARC FURNACES

The foremost thought in an operator's mind when making carbon steels in electric-arc furnaces is to be competitive with the open-hearth, in spite of the power and electrode cost disadvantage. To do this, the emphasis is always on elimination of delays. Minimum time between tap and charge, charging time, electrode changes, power delays, fast roof changes, and fast relines are all items of utmost importance if the objective of maximum tons/hour and lower cost is to be obtained.

100% Cold Charge

The general practice in the U.S.A. for making carbon steel in the large furnaces is to charge all cold scrap. Some operators use as much as 8% of the charge as cold pig iron to ensure a good carbon melt; others accomplish this through the use of recarburizing materials, such as broken electrodes, anthracite coal, petroleum coke, or graphite. The charge for large furnaces is usually divided into two or three parts. The first part is as close to 50% of the total charge as is possible, depending on the physical condition of the scrap, the second charge consists of all (or at least two-thirds) of the remaining scrap charge, and the third, if necessary, is intended to be as small a portion of the total as is practical. Recently, it has seldom been possible to use only two charges because of the low bulk density of the scrap available on the market today. Furthermore, although some heavy scrap is desirable to protect the bottom when melting down the original charge, light scrap not only melts faster but also gives better protection to the roof and side walls when used in large top-charged furnaces powered by high-voltage taps.

A typical charge for a 22-ft dia. shell top-charged furnace tapping 130 tons of carbon steel is as follows:

	Heavy	*Light*	*Scale*	*Lime*
Front charge, lb	75,000	70,000	4000	3000
1st back charge, lb	25,000	60,000	5000	3500
2nd back charge, lb	...	50,000	5000	5500
Total, lb	100,000	180,000	14,000	12,000

Scale or ore, together with limestone or burnt lime, is often added in the first charge. This is usually added with the scrap in the charging bell. When using ore and limestone in this way, it is difficult to control the location of this material and it sometimes comes to rest in the area under the electrodes, causing poor conductivity of the electric current and slow melting. For this reason, some operators prefer either to place the limestone and ore outside the electrode circle or to add it with the back charges.

Melting

The original charge is melted until there is room in the furnace to add the first back charge. Some unmelted scrap remains around the side walls after 1½–2 h melting. The first and second back charges will take about 40–50 min each to melt in furnaces of 100-ton capacity and larger.

Refining

As soon as the last back charge is melted enough to obtain a representative test for carbon and residual elements, a sample is taken. Oxygen is normally now introduced through a lance or jet and rapid decarburization takes place. The use of oxygen not only expedites the oxidation of the heat, but also increases the temperature, builds the slag FeO to the desired level, and purges the heat of undesirable gases in a minimum of time. Burnt lime, ore, and fluorspar are added to build a basic slag with a lime/silica ratio of 2½–3 : 1.

Generally the lime and ore added with the charge or back charge are sufficient to ensure the necessary removal of phosphorus by the time all the scrap charge

is melted. The slag is allowed to flush off during the early part of the oxidizing period, thus preventing phosphorus reversion. Additional lime added during the later and hotter part of the working period carries on the necessary sulphur removal and holds the necessary iron oxide content to ensure a rimming action when a rimmed-steel heat is being produced. The usual slag volume is much lower than that used on an open-hearth heat, generally being 3–5% of the charge weight.

When the proper carbon level is reached, the oxygen is stopped and the slag is shaped to the proper lime/silica ratio and iron oxide content. Temperature adjustments are made and any additions needed are added, based on a final chemical analysis. In the case of rimmed-steel heats, a short injection of oxygen can be used just before tapping, to increase the slag iron oxide if necessary.

After tapping, the banks, slag line, and sometimes the side walls are repaired quickly by using either the dolomite-throwing machine or the new high-speed refractory guns or both. Electrodes are adjusted and added, if necessary, and the roof is swung aside ready to charge, the whole operation taking only 15–20 min on the average.

Hot-metal Practice

In electric-furnace shops where hot metal is available, additions have been made ranging from 20% to 40% of the total charge. This practice reduces charging time, electrode consumption, and to some degree the power consumption at the expense of somewhat lower metallic yield. The net decrease in tap-to-tap time realized by this practice and the relative cost of scrap and hot metal are the principal factors in determining the application of hot metal in electric furnaces. Early attempts with hot-metal practice were not altogether successful, but improved techniques and high scrap prices have made it more profitable.

Charging practice in general consists of first charging the furnace with as much medium scrap as possible and broad-arc melting until the electrodes reach the furnace bottom and form a pool of metal; at this point the hot metal is added. Some operators wait, however, until the first charge is almost melted before adding hot metal. After this charge is melted down, the balance of the scrap is back-charged as medium and light scrap. Scale, ore, lime, or limestone are added to the original charge, but the charging sequence has varied with individual practice. At present, one plant is adding the hot metal first and then lime, ore, and scrap.

The refining practice in furnaces where hot-metal additions are used is essentially the same as that used with 100% cold-metal scrap charge, with the exception that larger quantities of ore, lime, and oxygen are used. Increased lime is required because of the relatively high silicon and phosphorus contents of the hot metal.

Because of the high ratio of bath depth to hearth area in the normal electric furnace, a very careful practice must be developed in working an electric-furnace heat when hot metal is used. The oxygen content of the slag increases rapidly as ore, scale, or oxygen is used and the bath is generally too deep to ensure a good diffusion of the oxides throughout the bath. A local overheated spot or some irregularity on the banks or bottom will often cause a small boil, which will start a violent carbon–oxygen reaction, increasing in activity so rapidly that slag and steel is boiled out the door.

Early users of hot metal became discouraged when the heats reacted violently three or four times during the working period. Some operators actually raised the level of the side doors, plugged the tapping hole below the slag line, and tilted the furnace over and let it blow when this sudden reaction took place. Today, however, by charging the hot metal earlier and working the heat carefully, as much as 40% hot metal is being used without serious spill-outs. A good flush during the early part of the working period plus the use of additional lime or limestone reduces the phosphorus to the desired level.

Looking into the future, greater hearth area with shallower baths plus the use of the induction stirrer on carbon-steel electric furnaces will improve the mixing of the bath and slag during oxidation and minimize the occurrence of sudden blows and spill-outs when high percentages of hot metal are used. In general, it can be stated that operators in the U.S.A. have not yet developed the optimum hot-metal practice for the electric furnace.

ALLOY AND STAINLESS EXPERIENCE IN LARGE FURNACES

Although this paper has been purposely limited to plain carbon steels, brief mention should be made of melting alloy and stainless steels in large furnaces. The recent trends for these steels have also been towards larger furnaces. Many plants are producing the common grades of stainless steels in 20-ft furnaces with heat sizes of 80–95 tons and at production rates of 10–15 tons/h. The ability to use large furnaces for manufacturing stainless steels is due primarily to the development of improved practices using a high rate of oxygen input (up to 60,000 ft^3/h), thereby obtaining fast carbon elimination and minimum refractory damage. This high rate of oxygen input generates high temperatures and some method of chilling the bath quickly must be used. Many operators tap the heat into a ladle as soon as the slag is partly reduced, in order to cool the metal down to a normal operating temperature and also to cool the furnace refractories. They then return the metal to the furnace and finish the heat under a reducing slag.

Alloy steels of the bearing type, aircraft grades, and other grades specifying high-quality standards are today made successfully in 90-ton heats, compared with the past practice of restricting their manufacture to less than 50-ton heats. Some companies are using 22-ft furnaces and are making these grades successfully in 100–120-ton heats at production rates of 15 tons/h.

OPERATING DATA

Table II is a summary of recent operating data collected from several plants in the U.S.A. using

Table II

LARGE ELECTRIC-FURNACE OPERATING STATISTICS FOR PRODUCTION OF CARBON STEEL

	1952*		1957*				
	100% Cold Charge		100% Cold Charge			Hot Metal in Charge	
Furnace shell dia., ft	18	20	20	22	24	22	24
Transformer capacity, kVA	20,000	25,000	25,000	30,000	35,000	33,000	35,000
Electrode dia., in.	20	20	20	24	24	24	24
Av. heat size, short tons	65	90	105	150	180	140	185
Tap-to-tap time, h	4·4	4·8	4·2	4·4	6·0	5·6	6·2
Ingot production, tons/h	13·5	18·3	25·0	34·1	30·0	25·0	30·0
Power consumption, kWh/ton	525	525	516	554	470	485	500
Electrode consumption, lb/ton	12	12	9·0	12·5	11·0	11·0	11·3
Metallic yield, %	91	91	92·1	91·5	92·0	89·1	88·9
Ore consumption, lb/ton	50	50	110	120	100	145	170
Lime and limestone consumption, lb/ton	105	105	90	125	90	99	100
% Hot metal	...	...	...	...	...	20–25%	25–30%

* 1952 data extracted from the 1953 Battelle report, and represent average operating data in the U.S.A. for the production of carbon steel in electric furnaces using 100% cold charges.
* 1957 data taken from actual operating data submitted to the authors by companies operating large furnaces for carbon-steel ingots. The data do not represent any one plant's performance, but are averages of statistics submitted by furnace size.

20-ft shell furnaces and larger for making carbon-steel ingots of grades similar to normal open-hearth grades. The data do not necessarily represent information by individual plants; they are averages of the data from different shops, and show what is being done by each of the three furnace sizes for both 100% scrap charge and partial hot-metal charges. Data published in a report[2] representing 1952 statistics for 18-ft and 20-ft shell furnaces are included to show the improvement in production rates since that time.

Variation in melting practice from one plant to another and differences in melting-shop facilities and designs substantially affect the operating statistics of different shops. Some of these effects, however, are averaged out in summarizing the data by furnace size.

The table indicates that production rates on all cold-charge practice have increased by 35% or more since 1952 and that the larger furnaces have accounted for a greater portion of this increase. It also shows that for the 20-ft shell furnace there has been an increase in production rate, most of which must be attributed to improved operating practice, improved auxiliary facilities, and increase in ratio of top-charged to door-charged furnaces being operated.

The data indicate that the same production rates are obtained on the 24-ft furnace when either an all-cold charge or a 25–30% hot-metal charge is used. However, these data compare a well established practice using an all-cold charge against data representing very limited experience with 25–30% hot metal. The operators of these shops indicated to the authors that a 20% increase in production is expected when using 20–25% hot metal after more experience has been obtained with the practice.

The data for the 22-ft furnaces actually show a much better ton/hour performance using all-cold charge than when using hot metal. One cold-metal shop with an outstanding heat-time performance is producing carbon steels at the rate of 34·1 tons/h, which is as good as could be expected when using hot metal. The comparison figure of 25 tons/h using hot metal on the 22-ft furnace is somewhat lowered by data which have some alloy-steel statistics included with the carbon-steel statistics. The table indicates that the good production performance on the all-cold scrap charged 22-ft furnace is somewhat offset by a higher kWh consumption and a higher electrode consumption than the hot-metal practice on the 22-ft furnace. The chart also shows the lower yield normally expected when using hot metal compared with the yield on an all-cold scrap charge.

The data in Table II generally verify the forecasts of estimated production rates made five years ago and lead one to believe that estimates of 40–45 tons/h at present forecast from very large electric furnaces are not impossible in the near future.

ECONOMICS OF ELECTRIC *v.* OPEN-HEARTH FURNACES FOR PLAIN CARBON INGOTS

Probably the best U.S. study of the relative economics of electric and open-hearth furnaces for the production of plain carbon steels was made by the Battelle Memorial Institute in 1953 in the report by Case and others[2] for the utility and coal industries. This report has created considerable controversy in the U.S.A., resulting from the varied opinions and interpretations of the results. A number of individual companies have since made their own investigations of this subject. In general, the Battelle report stated that when all factors were considered, *for all-cold charges*, the electric furnace was more economical than the open-hearth, while for hot-metal practice the open-hearth was favoured. This was qualified in the report by statements to the effect that future

increases in fuel oil costs plus development and refinements of hot-metal usage in the electric furnace would tend to favour the electric furnace.

Capital Costs

In regard to capital costs, there is little or no disagreement that the investment cost per ingot ton for electric furnaces is about 50% less than that of a comparable tonnage open-hearth shop. The figures obtained in the Battelle study and in other company studies from 1953 to 1956 indicated an approximate investment cost of $21 to $28 per annual ingot ton for the electric furnace for a ½–1 million annual ton plant. This assumes that sufficient electrical power is available from independent sources. While future cost studies may alter the actual dollar investment cost comparison, the difference will probably remain in the region of 40–50% lower investment cost per ton for the electric furnace. This difference is largely associated with the smaller size of the electric-furnace plant plus the lighter building foundations, cranes, ladles, and other major capital equipment items per unit of production.

The investment cost advantage of the electric furnace is of major importance to companies with limited short-range capital for expansion or entry into the steel market. It is also of importance to companies having sufficient long-range capital when the return on invested capital with incurred interest charges is considered. As will be seen later, the capital investment charges must be considered realistically in the cost per ingot ton produced and results in an advantage in this item of 'cost above' for the electric furnace.

Material Costs

An accurate comparison of material costs in the open-hearth and electric furnace is probably the most difficult to make because of the major changes which occur in costs of basic steelmaking materials, on both a short-range and a long-range basis. This problem is best resolved by long-range studies of the probable price and availability of all raw materials including ore, scrap, and hot metal. This study requires individual company judgments. The tangible factors which are important in evaluating material costs are as follows:

(i) Scrap supplies will probably never be sufficient to support, in any country, the major steel ingot tonnage requirements over a long period. This makes the costs of hot metal, pig iron, and scrap of major importance in determining the effects of material costs on the relative economics of electric and open-hearth furnaces. In any given country, the long-range relative cost differential of these materials is associated with the overall ratio of iron ore usage and hot-metal production to ingot production and capacity. When demand for scrap rises as a result of too high a percentage of ingots being produced from scrap, the cold-charged electric furnace is at a severe disadvantage when compared with hot-metal open-hearth furnaces producing plain carbon steels. The use of synthetic scrap produced by direct reduction of iron ore is one possible solution to this problem

(ii) The metallic yield in the electric furnace on a cold- or hot-metal charge is higher than that in the open-hearth. This results from the rapid melting in the electric furnace and from the greater loss of metallics in the waste gases of the open-hearth process. There is also reason to believe that for comparable charges the required slag volume will be lower in the electric process, which also results in higher metallic yield. The yield advantage will probably be a minimum of 1% to a maximum of 3% in favour of the electric process

(iii) The top-charged electric furnace can use a cheaper grade of scrap for melting plain carbon ingots. This is associated with the class of scrap (heavy or light melting) and with scrap preparation (bundled or miscellaneous). Because the ability to top-charge light bulky scrap, compared with box charging for open-hearth furnaces, the electric furnace will probably maintain some cost advantage in type of scrap. There is a long-range trend in the U.S.A. towards lighter purchased scrap. In addition, because of its speed of melting, the electric furnace generally requires less cold iron per ingot ton for melt control than the cold-charged open-hearth process.

Cost Above*

While most items mentioned thus far favour the electric furnace, it is in the region of 'cost above' that the advantages of the open-hearth assert themselves to the greatest extent. The major items adversely affecting the cost above of the electric process are associated with fuel costs. In the U.S.A. in the past and today, the cost of power for melting plus the electrode costs have been substantially above the fuel costs for open-hearth furnaces both for cold-metal and hot-metal practices. Also, experience has shown that mould and stool costs per ingot ton have been higher for electric-furnace than for open-hearth plain carbon steel. Items of cost above favouring the electric furnace are repairs and maintenance costs (as a result of lower refractory usage per ton plus faster rebuilds or greater availability) and somewhat lower labour hours when large electric furnaces are compared with similar-size modern open-hearths. However, the importance of each of the above items is significantly affected by the tons per operating hour obtainable from the electric furnace and open-hearth being compared.

In this study, no specific costs were assigned to the individual items. Because of the changing price of individual items of cost, it is generally best to compare these processes by differences rather than by total dollars. Many comparisons in the past have been somewhat unfair as a result of comparing a new electric shop *v.* an old open-hearth shop or *vice versa*, or comparing shops having widely different furnace sizes.

The first questions that need to be answered before beginning a reasonable economic comparison are the annual tonnage requirement and, most important, the individual furnace size. The trend in the U.S.A. in recent years has been toward larger and larger electric and open-hearth furnaces, not only for plain carbon steels but also for alloy steels. This factor alone has a large effect on the cost above as a result of significant changes in tons produced per operating hour. To illustrate this effect, the best U.S. open-hearth furnaces can produce 350-ton heats in 10 h tap-to-tap, while the best 150-ton open-hearth furnaces with similar facilities generally do no better than 8 h

*All items of ingot cost above material costs.

tap-to-tap; this yields 35 tons/h for the larger furnace and 19 tons/h for the smaller furnace. In one electric shop producing only stainless and alloy steel, a 45-ton electric furnace produces a heat of stainless steel in 7 h tap-to-tap, while an adjacent 90-ton furnace produces the same grade in 9 h tap-to-tap; this yields 6·5 tons/h for the smaller furnace and 10 tons/h for the larger furnace, an improvement of 38·5%. From the above illustrations, it is evident that furnace size has an extremely large effect on tons per hour and, in turn, on all items of cost above that are affected by tons per hour. Thus, if one compares the cost above of a 40-ton electric or open-hearth furnace with that of a 400-ton open-hearth furnace, a great cost advantage will result for the larger furnace. Any smaller differential in furnace size will still yield some advantage to the larger unit. This factor must be considered and appreciated when evaluating the economics of the two processes. In any particular ingot expansion programme being considered, many factors such as rolling-mill capacity and auxiliary equipment, product mix, and order requirements will define the proper size of the melting shop and steelmaking furnaces. One factor limiting electric-furnace size in some companies' evaluation has been the desire to be able to convert the electric furnaces from plain carbon to alloy and stainless steels when market conditions fluctuate. An attempt to do this automatically limits the size of the individual electric furnace since, at least today, there is a lack of information regarding the ability of electric furnaces as large as 200 tons to produce good-quality alloy and stainless steels (plus the order requirement problem). For the purpose of this paper, it is assumed that the attainment of the best possible cost per ton is the objective in both the open-hearth and the electric furnace and so the larger furnaces have been selected for comparison purposes.

The current U.S. majority opinion definitely indicates that, for non-integrated cold-metal operation, the electric furnace has a sizeable cost advantage. As a result, it can be expected that there will be future expansion in certain areas of the U.S.A. in the use of electric furnaces for plain carbon ingots.

In the area of competing with hot-metal open-hearths, it does not at present appear that the electric furnace is competitive on a cost basis in the U.S.A. While total cost difference may be relatively small, over a period of years this difference could have a sizeable effect on company profits or earnings between electric furnace and open-hearth plants. The hot-metal electric practice in the U.S.A. is not sufficiently developed to yield accurate data. However, some cost estimates were made on the basis of giving the hot-metal electric furnace the benefit of any doubts. To make the electric furnace more competitive, a large change in the relative cost of scrap *v.* hot metal is needed, which is not too likely over a long period. Also, a definite change in relative cost of fuel oil *v.* electric power and electrode costs is needed. Furthermore, the authors believe that a change in design of the electric furnace is required for most efficient hot-metal usage: the furnace should be larger and have more hearth area and less bath depth (or, alternatively, a stirred bath). Whether any company will be willing to risk sufficient capital in attempting to overcome the disadvantages of the present electric-furnace design for hot-metal usage is questionable. Furthermore, the open-hearth has an inherent advantage in that, because of the larger number of present units and greater number of experienced open-hearth personnel, more talent is available for programs directed towards cost reduction and improved furnace operation. Electric-furnace efficiency is also steadily improving, as has been shown; the relative rates of improvement recently are important and have been interesting to observe. Lastly, no mention has been made of a third possibility of future expansion in the U.S.A.—the oxygen converter for integrated plants. This process will also exert a major influence over expansion of the open-hearth and electric processes. In general, the most realistic hope for immediate electric-furnace expansion in the U.S.A. is for all-cold charged operations, with the possible use of direct-reduced iron charges. In the meantime, improvements in furnace and equipment design and furnace operation are necessary if the electric furnace is to replace integrated hot-metal open-hearth shops.

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The Diffusion of Hydrogen in Steel at Temperatures of −78° to 200°C

By J. D. Hobson, Ph.D., F.R.I.C., A.I.M.

SYNOPSIS

Using specimens cut from large forgings, it is shown that the diffusion of hydrogen in steel does not follow the predictions of the accepted exponential equation at temperatures below about 150°C. The diffusion constant at a given temperature varies from steel to steel, but the square law relating rate of evolution and specimen diameter is followed approximately. Results of an experiment on a large forging agree with laboratory measurements.

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THE DIFFUSION CONSTANT for hydrogen in steel is required for theoretical calculations on heat-treatment cycles for hydrogen removal, but is difficult to measure owing to an appreciable rate at room temperature. Several workers have measured permeation rates, using some form of diaphragm, but this is a complex function involving adsorption and solubility. Sykes, Burton, and Gegg[1] used the permeability constants of Bennek and Klotzbach[2] and Smithells and Ransley,[3] coupled with the solubilities determined by Sieverts[4] to calculate the diffusivity constant of hydrogen in α- and γ-iron. Table I gives their results, with additional values calculated from their equations:

$$D = 7{\cdot}6 \times 10^{-4}\, e^{-1150/T} \text{ for } \alpha\text{-iron}$$

$$D = 1{\cdot}5 \times 10^{-2}\, e^{-1150/T} \text{ for } \gamma\text{-iron.}$$

From the table the calculated rate changes by a factor of 15 between 20° and 600° C, but experience in laboratory experiments suggests that a much larger difference in rate occurs. Whereas at high temperatures the diffusion constant found by evolution was in reasonable agreement with the value calculated from permeability,[5] at room temperature both Sykes[1] and Hobson[7] found serious anomalies.

Practical methods for the direct determination of the diffusion constant may be based on measurements of loss of hydrogen from specimens with hydrogen either added by the pressure method[6] or present naturally.[7] In the absence of apparatus for high-pressure hydrogenation, rates of diffusion at temperatures in the range −78° to 200° C have been investigated using specimens cut from large forgings. Analyses of the steels examined are given in Table II.

EXPERIMENTAL METHODS

Specimens were cut in a radial direction from large forgings, using only the inner zones having a reasonably uniform hydrogen content. To simplify mathematical analysis of the results the specimens were cylindrical, with a length to diameter ratio never less than 4 : 1 and often as high as 20 : 1, thus ensuring that the diffusion in the specimens would be mainly radial towards the freshly exposed surfaces and swamping the slight longitudinal gradient arising from diffusion in the forging. Care was taken to minimize accidental loss of hydrogen during sample preparation by refrigeration during storage and cooling during machining.

The diffusion experiments at room temperature were carried out using storage under mercury in a special inverted burette (Fig. 1*a*), or in an evacuated chamber of known volume (Fig. 1*b*). For work at 100° C the burette was steam-jacketed, as shown in Fig. 1*c*.

For work at −78° C, the samples were stored in solid carbon dioxide. At 50° and 200° C, an oven with an air-circulating fan was used for large specimens; smaller specimens were heated in water or oil to obtain rapid temperature equilibrium.

The gas evolved from specimens stored under mercury was removed for analysis and was principally hydrogen, though small amounts of methane were present in the gas from the plain carbon steels. Methane, if present, was calculated to its hydrogen equivalent. Undiffused hydrogen was determined by the vacuum-heating method at 600° C. For work at room temperature the evolution curves were obtained by periodic readings of the burettes, but at −78° and 200° C the curve was obtained by determinations of residual hydrogen made after varying periods of time on a number of specimens cut from corresponding positions in the original forging.

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Table I

VALUES OF DIFFUSION CONSTANT OF HYDROGEN IN α- AND γ-IRON

(*a*) given by Sykes, Burton, and Gegg
(*b*) additional results calculated from their equation

Temperature, °C	Diffusion Constant, $cm^2 \times s^{-1}$			
	α-Iron		γ-Iron	
	(a)	(b)	(a)	(b)
1200			$2{\cdot}5\times10^{-4}$	
1100			$1{\cdot}9\times10^{-4}$	
1000			$1{\cdot}3\times10^{-4}$	
900			$8{\cdot}7\times10^{-5}$	
800	$2{\cdot}69\times10^{-4}$		$5{\cdot}7\times10^{-5}$	
700	$2{\cdot}34\times10^{-4}$		$3{\cdot}1\times10^{-5}$	
600	$2{\cdot}04\times10^{-4}$		$1{\cdot}55\times10^{-5}$	
500	$1{\cdot}70\times10^{-4}$		$6{\cdot}4\times10^{-6}$	
400	$1{\cdot}38\times10^{-4}$			
300	$1{\cdot}00\times10^{-4}$			
200	$6{\cdot}7\times10^{-5}$			
100	$3{\cdot}5\times10^{-5}$			
20	$1{\cdot}5\times10^{-5}$		$1{\cdot}9\times10^{-11}$	
−78		$2{\cdot}1\times10^{-6}$		

Table II

ANALYSES OF STEELS USED IN DIFFUSION EXPERIMENTS

Steel	Analysis, %							
	C	Si	S	P	Mn	Cr	Ni	Mo
A	0·30	0·24	0·012	0·022	0·67	0·75	2·64	0·48
B	0·17	0·26	0·294	0·021	0·86	14·0	0·38	0·51
C	0·42	0·25	0·016	0·019	0·63	0·74	2·51	0·48
D	0·34	0·15	0·013	0·015	0·85	0·14	0·17	...
E	0·79	0·33	0·046	0·038	0·85	0·95	0·09	...
F	0·77	0·27	0·042	0·027	0·92	1·50	0·11	0·30
G	0·83	0·26	0·031	0·026	0·89	1·41	0·19	0·30
H	0·28	0·19	0·016	0·018	0·69	3·06	0·16	0·47
I	0·27	0·34	0·010	0·006	0·57	3·18	0·22	0·53

EXPERIMENTAL RESULTS

Effect of Specimen Size

Glass-blowing facilities restricted the maximum cylinder diameter to 45 mm; when sufficient material was available the specimens were tested in a geometrical series of diameters, (ratio=$\sqrt{2}$), these being 45·0, 31·8, 22·5, 15·9, 11·25, 7·95, and 5·625 mm. The solutions of problems in heat flow have been provided in tabular form by Russell,[9] and with suitable choice of analogy of variables and constants the same equations can be applied to problems of hydrogen diffusion. The basic equation for diffusion in infinitely long cylinders is $\tau=kt/r^2$; τ is a time function related to the residual hydrogen fraction U, where $U=\dfrac{\text{residual hydrogen}}{\text{initial hydrogen}}$. The diffusion constant k (cm^2/s), the radius r (cm), and time t (s) are the other variables. From the equation the time required to reach a given hydrogen distribution should be proportional to the square of the specimen diameter. The theory has been tested on two steels of widely differing composition. Steel *A* was a 2¼%Ni–¾%Cr–½%Mo steel; *B* was a 14%Cr free-cutting steel. The results are shown as graphs of residual hydrogen fraction U plotted against time in

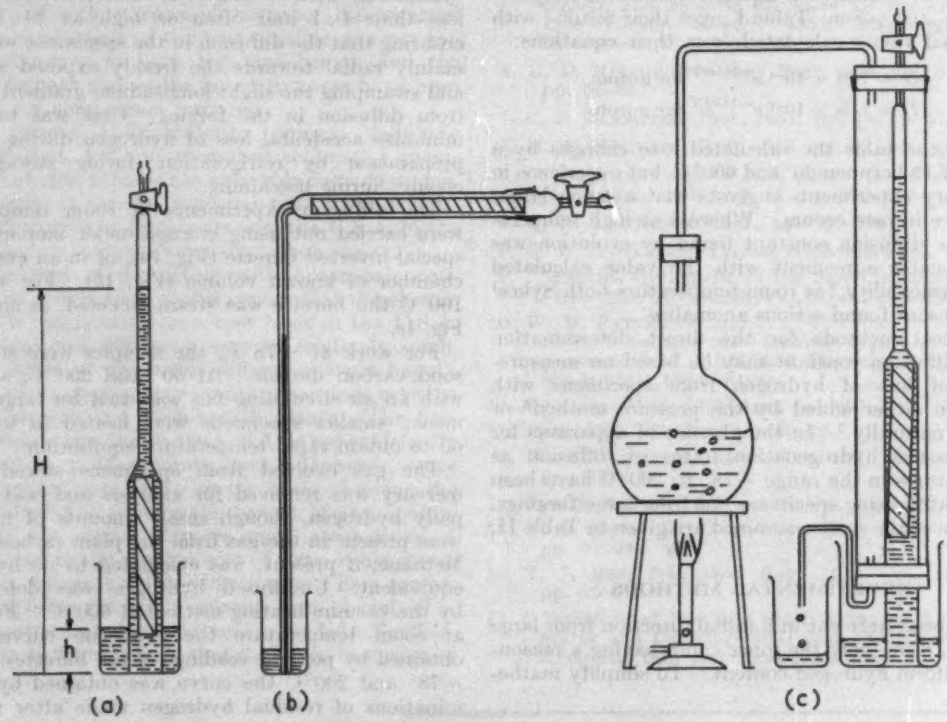

Fig. 1—Apparatus for the collection of hydrogen evolved from steel at 100°C and at room temperature

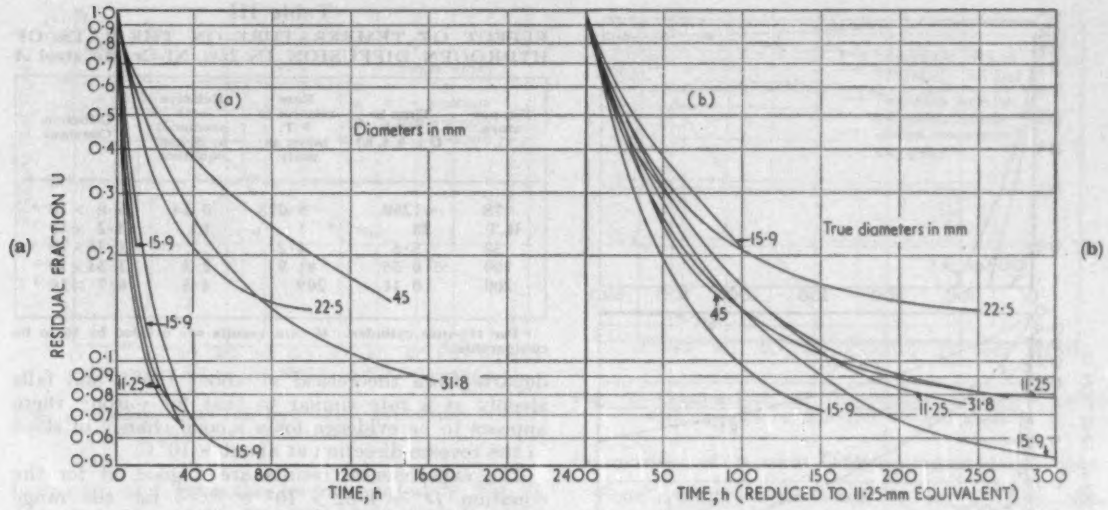

Fig. 2—(*a*) Effect of cylinder diameter on evolution rate for 2·5%Ni–Cr–Mo steel; (*b*) Evolution curves reduced by inverse square law to common time scale

Figs. 2*a* and 3*a* and against time reduced to a common diameter of 11·25 mm in Figs. 2*b* and 3*b*. Theory predicts that for the latter the curves for a given steel should then coincide; in practice there is still considerable scatter of the evolution curves but this is random for the sizes for each steel. It is concluded that the square law is approximately followed, and some reasons for the scatter are discussed later.

Comparison of the two steels shows that for a specimen of a given size the evolution is slower by a factor of about 40 for 14%Cr steel *B* than for 2¼% Ni–Cr–Mo steel *A*. On several occasions pairs of test-pieces were used in duplicate experiments; in some cases close agreement was found, and in other cases the specimens gave curves of similar form but differing by a factor of 2 in time scale. The apparent reduction of the diffusion rate when the residual fraction *U* falls to about 0·1 is not entirely genuine. Owing to the design of the apparatus the most sensitive measurements are those made at the beginning of the experiment when the gas pressure is low. Towards the end of the experiment when gas is evolved very slowly, experimental accuracy is reduced by the effects of fluctuations in barometric pressure and laboratory temperature, and the difficulty of avoiding trapped gas. In some experiments where gas evolution had apparently ceased the gas was removed and collection restarted, and the increased sensitivity enabled the continuation of diffusion to be detected.

Effect of Temperature

From Table I, it will be seen that Sykes' equation[1] predicts a diffusion rate at 200° C approximately 4·5 times as great as at room temperature, and reduced by a factor of 7 between 20° and −78° C. Using steel *A* experiments were carried out at −78°, 50°, 100°, and 200° C for comparison with the

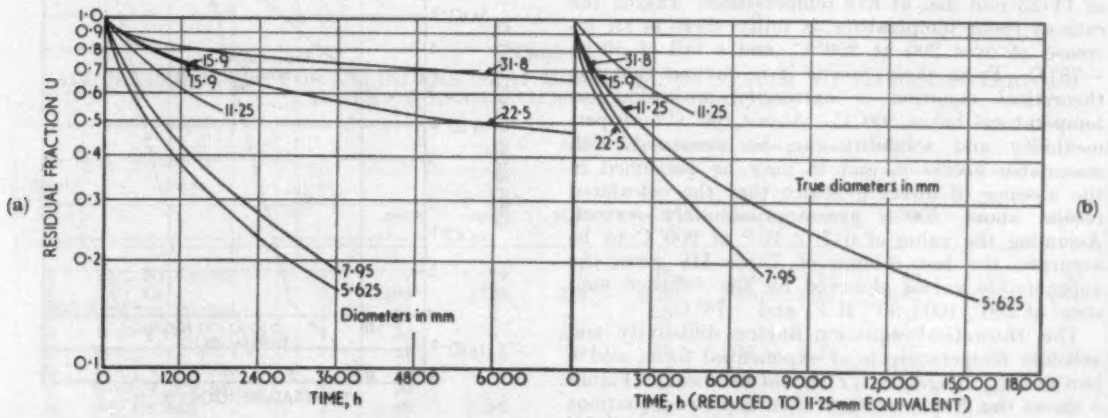

Fig. 3—(*a*) Effect of cylinder diameter on evolution rate for 14%Cr steel; (*b*) Evolution curves reduced by inverse square law to common time scale

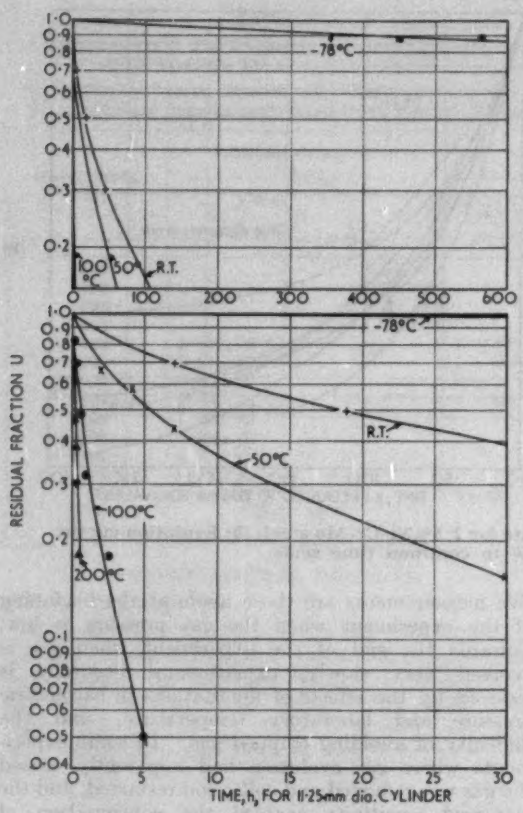

Fig. 4—Effect of temperature on rate of hydrogen evolution from 2·5%Ni–Cr–Mo steel *A*

room temperature results. Most of the test-pieces were 11·25 mm dia. but a few 45-mm specimens were used at 200° C and the times for the latter have been divided by 16 to facilitate comparison. The results are given in Fig. 4, plotted at two different scales to show the extremes of rate. Table III gives the time in hours required to reach $U=0·5$ for cylinders of 11·25 mm dia. at five temperatures. Taking the rate at room temperature as unity there is an increase of over 200 at 200° C, and a fall of 50 at −78° C. From these results it is obvious that the theoretical equation is extremely misleading at temperatures below 200° C. Above 200° C both permeability and solubility can be measured with reasonable accuracy, and it may be presumed in the absence of direct evidence that the calculated results above 200° C are approximately correct. Assuming the value of $6·7 \times 10^{-5}$ at 200° C to be accurate, the last column of Table III gives the approximate values observed for the diffusion constant at 200°, 100°, 50°, R.T., and −78° C.

The theoretical equation linking diffusivity and absolute temperature is of exponential form, and a plot of $\log_{10} D$ against $1/T$ should be linear. Figure 5 shows the graphs plotted from the two equations quoted earlier and the four points between −78° C and 100° C calculated from the results. The graph

Table III

EFFECT OF TEMPERATURE ON THE RATE OF HYDROGEN DIFFUSION IN 2¼% Ni–Cr–Mo steel *A*

Temperature, °C	Time to reach $U = 0·5$, h*	Rate relative to R.T. taken as unity	Relative rate predicted by Sykes' equation	Diffusion Constant
−78	~1250	0·018	0·14	$5·8 \times 10^{-9}$
R.T.	23	1	1	$3·2 \times 10^{-7}$
50	5·5	4·2	...	$1·35 \times 10^{-6}$
100	0·55	41·9	2·3	$1·34 \times 10^{-5}$
200	0·11	209	4·5	$6·7 \times 10^{-5}$

* For 11½-mm cylinder. 45-mm results are divided by 16 to be comparable.

departs from theoretical at about 125° C and falls steeply at a rate similar to that for γ-iron; there appears to be evidence for a second change of slope in the reverse direction at about −10° C.

The experimental results are a good fit for the equation $D = 1·82 \times 10^{2}\ e^{-6075/T}$ for the range 20–110° C, equivalent to an activation energy of about 12 kcal/g-atom. Richardson[8] in discussing the paper of Sykes *et al.* pointed out that their equations indicated 12 kcal as the activation energy for diffusion in γ-iron, but only 2 kcal for α-iron, whereas other workers obtain 9–10 kcal for hydrogen in iron and not less than 6 kcal in other metals.

A limited number of experiments on steel *B* show an increase of rate of 115 between room temperature and 100° C. At −78° C, 3%Cr–Mo steel *H* had approximately one twentieth of the room temperature rate.

Effect of Storage Conditions

Cylinders of steel *A* were stored at room temperature in air, under mercury, and in a low pressure of

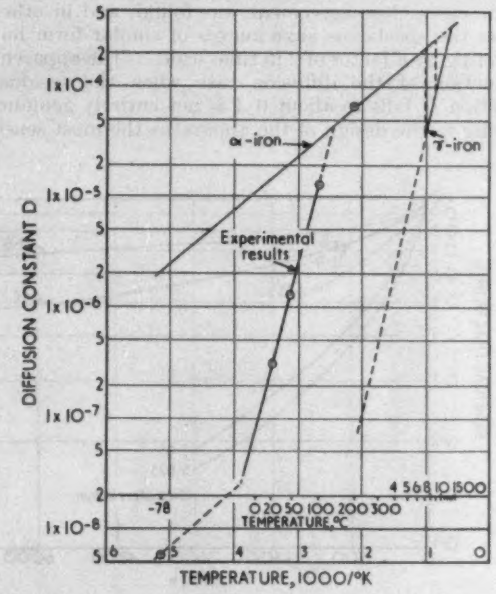

Fig. 5—Observed and calculated rates of diffusion of hydrogen in iron

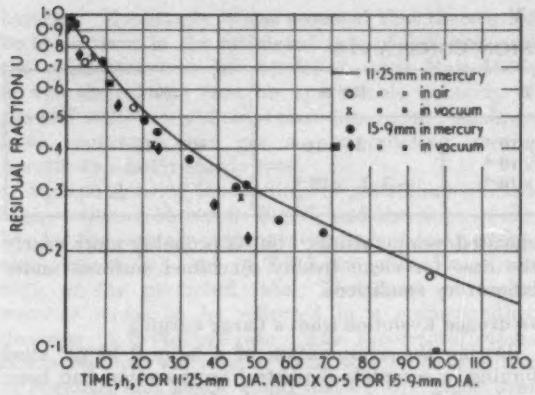

Fig. 6—Comparison of hydrogen evolution in air, mercury, and vacuum

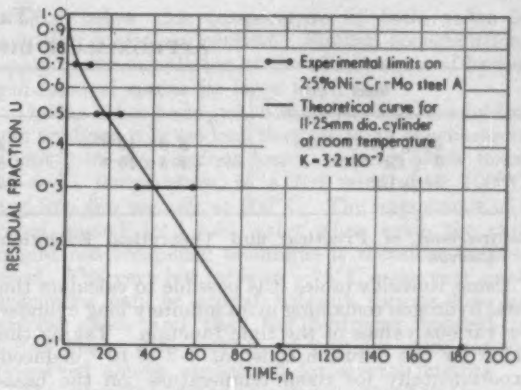
RESIDUAL FRACTION U
Experimental limits on 2·5%Ni-Cr-Mo steel A
Theoretical curve for 11·25mm dia. cylinder at room temperature
K = 3·2 x 10⁻⁷
TIME, h

Fig. 7—Comparison of theoretical evolution curve with results on 2·5%Ni–Cr–Mo steel *A*

hydrogen, and gave the results plotted in Fig. 6. The line represents two cylinders stored under mercury, giving concordant results. Bearing in mind the experimental difficulties it seems likely that the storage conditions have had no significant effect on the rate of hydrogen evolution.

Effect of Steel Composition

In addition to the experiments using 2½%Ni–Cr–Mo steel *A* and 14%Cr steel *B*, a number of experiments were made using samples from seven other heats (steels *C*–*I*). The results obtained are summarized in Table IV which gives the maximum and minimum times found experimentally for samples from each steel to reach residual hydrogen fractions of 0·7, 0·5, and 0·3 on the basis of 11·25-mm dia. specimens. It will be seen that diffusion is most rapid in the 2½%Ni–Cr–Mo steels, slightly slower in the carbon and carbon–chromium steels, appreciably slower in 3%Cr–Mo steel, and extremely slow in the 14%Cr free-cutting steel. Assuming the value of $6{\cdot}7 \times 10^{-5}$ to be correct at 200° C for the 2½%Ni–Cr–Mo steel, the approximate diffusion constants for the 3%Cr–Mo and 14%Cr steels are given in Table V.

Comparison of 'Natural' and Impregnated Hydrogen

Four results were available for 0·75-in. dia. cylinders of low-alloy steel impregnated by the high-pressure method.[7] Assuming the inverse square law to hold, Table VI gives some results on these steels calculated for 11·25-mm cylinders. Comparison with Table IV shows that the 2½%Ni–V steel cut from a forging lost hydrogen after impregnation at a similar rate to the fastest steel with 'natural' hydrogen. But the three steels in which rolled billet was used for high-pressure hydrogenation were all appreciably faster. It therefore appears possible that the diffusion rate may be altered by a factor of 2 according to the method used for hot working, or the difference might be due to changes in variables such as grain size, microstructure, or minute traces of porosity. On the other hand, the diffusion rate is so sensitive to temperature that changes of about 10° C cause doubling of the diffusion rate near room temperature. The proposed equation gives $1{\cdot}26 \times 10^{-7}$ for the diffusion constant at 15° C, and $2{\cdot}56 \times 10^{-7}$ at 25° C. At present it is not possible to decide whether the apparent difference of forged and rolled material is genuine or merely due to slight differences in laboratory conditions; any further work will require apparatus with thermostatic control.

Table IV

CALCULATED TIMES FOR CYLINDERS OF 11·25 mm DIA. OF STEELS *A*–*I* TO REACH VARIOUS VALUES OF RESIDUAL HYDROGEN FRACTION *U*

Steel	Type	No. of Expts.	Time to reach residual hydrogen fraction *U*, h								
			U = 0·7			*U* = 0·5			*U* = 0·3		
			mean	max.	min.	mean	max.	min.	mean	max.	min.
A	2½% Ni–Cr–Mo	10	7	10	5	19	24	14	44	58	33
B	14% Cr	7	690	1320	310	2080	2960	1500	5640	6720	4560
C	2½% Ni–Cr–Mo	1	11	...	...	28	...	...	78	...	...
D	0·34% C	1	32	...	...	63	...	...	108	...	...
E	0·8% C–1·0% Cr	2	11	12	10	27	31	22	72	88	56
F	0·8% C–Cr–Mo	1	26	...	...	62	...	...	150	...	...
G	0·8% C–Cr–Mo	1	20	...	...	35	...	...	85	...	...
H	3% Cr–Mo	2	48	60	35	108	140	76	250	360	145
I	3% Cr–Mo	1	85	...	...	...	...	...	...	...	...

Table V

APPROXIMATE DIFFUSION CONSTANTS

Steel	−78°C	R.T.	100° C	200° C
2¼% Ni–Cr–Mo	$5{\cdot}8\times10^{-9}$	$3{\cdot}2\times10^{-7}$	$1{\cdot}34\times10^{-5}$	$6{\cdot}7\times10^{-5}$
3% Cr–Mo	$\sim2{\cdot}5\times10^{-9}$	$\sim5{\cdot}0\times10^{-8}$	...	...
14% Cr	...	$\sim2{\cdot}8\times10^{-9}$	$\sim3{\cdot}2\times10^{-7}$	...

Comparison of Practical and Theoretical Evolution Curves

Using Russell's tables it is possible to calculate the total hydrogen remaining in an infinitely long cylinder for various values of the time function. Taking the value for the diffusion constant $3{\cdot}2\times10^{-7}$ deduced experimentally for room temperature, on the basis of a cylinder of 1·125 cm dia., $r^2 = 0{\cdot}316$, substitution in the equation $\tau = kt/r^2$ gives $t = 272\tau$ (measuring t in hours) and the following relationship between time and remaining fraction U:

τ	0·02	0·04	0·05	0·06	0·08	0·10
t, hours	5·5	11·0	13·8	16·5	22·0	27·5
Fraction U	0·706	0·586	0·555	0·512	0·449	0·383

τ	0·15	0·20	0·30	0·40	0·50
t, hours	41·3	55	82·5	110	138
Fraction U	0·292	0·218	0·115	0·067	0·037

Figure 7 shows a graph of this evolution curve on which are inserted the mean and extreme values obtained on 2¼%Ni–Cr–Mo steel *A* taken from Table IV.

The agreement between experiment and theory is quite good at values of $U = 0{\cdot}7$, 0·5, and 0·3, but diffusion is becoming slower than theoretical at $U = 0{\cdot}1$, indicating either some undiffusible hydrogen, or cumulative errors in the experimental results. The close agreement here indicates that there is no serious error in the theoretical value of $6{\cdot}7\times10^{-5}$ for the diffusion constant at 200° C, which was used together with comparison of evolution rates to derive the room temperature constant.

An underlying assumption in this use of Russell's tables is that there is instant equilibrium between the surface of the cylinder and the external atmosphere; i.e. the hydrogen concentration falls instantaneously from $U = 1$ to $U = 0$ at the surface when the experiment begins. This is known to be untrue for large forgings, billets, etc., having a scaled surface and at elevated temperatures,[10] but is probably more nearly the case for clean freshly machined surfaces under laboratory conditions.

Table VI

CALCULATED TIMES FOR CYLINDERS OF 11·25 mm DIA., TO REACH VARIOUS VALUES OF RESIDUAL HYDROGEN FRACTION *U*

Hydrogen introduced by High Pressure Method

Steel	Type	Origin	Time to reach residual fraction U, h		
			$U = 0{\cdot}7$	$U = 0{\cdot}5$	$U = 0{\cdot}3$
J	2¼% Ni–V	Forging	3–6	10·5–16	28–39
K	0·4% C	Rolled billet	2	7	21
L	1% Ni	,, ,,	2	7	21
M	2% Ni–Cr–Mo	,, ,,	1·7	5·5	15·5

Hydrogen Evolution from a Large Forging

During the examination of a large 0·34%C steel forging, a complete diametral cross-section had been analysed for hydrogen and the forging was known to contain about 4·6 ml H_2 per 100 g at its axis. A portion of this forging of 31 in. dia. weighing over 2 tons was used for an experiment designed to check the diffusion rates calculated from laboratory test-pieces of ¼ in. to 1¾ in. dia. A small flat area was machined on the cylindrical surface at mid-length, and a stainless steel funnel of effective diameter 3·44 in. was bolted down using an O-ring seal. The funnel carried a calibrated glass burette and mercury reservoir, so that gas released at the surface of the forging could be calculated from measurements of volume, pressure, and temperature.

A calculation using a method based on Russell's tables,[10] and a diffusion constant for carbon steel of $4{\cdot}2\times10^{-7}$ at room temperature (deduced from laboratory experiments on other specimens of the same forging) has given an estimated rate of release of 8·82 ml (N.T.P.) per year for the area of collection, and the burette was designed to hold about 45 ml.

Collection started on August 1st, 1956, and frequent visits were made to the apparatus, stored in a large works building, but no gas was visible in the

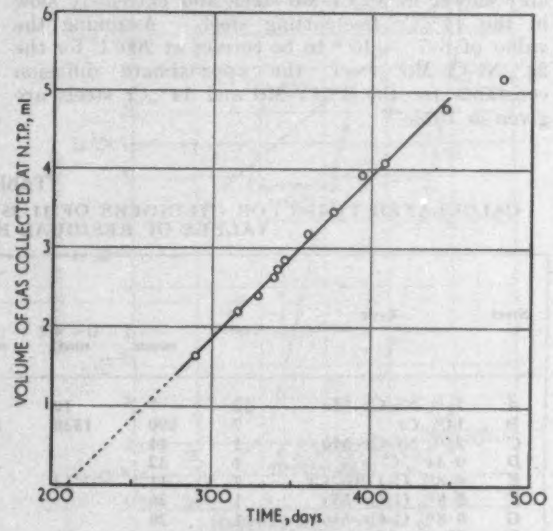

Fig. 8—Evolution of gas from part of a large forging (weight 2·2 tons, dia. 30·8 in.)

burette. Eventually it was assumed that there must be some error in the estimated rate of diffusion and the apparatus was left unvisited until May 1957; it was then found that an appreciable quantity of gas had collected, and since that date regular readings have confirmed that gas is accumulating in the burette at a fairly steady rate.

A graph showing the readings of gas volume plotted against time is shown in Fig. 8, and the slope of the line for the summer months is equivalent to an evolution rate of $7{\cdot}5_6$ ml (N.T.P.) per year, i.e. about 86% of the predicted rate. The onset of cooler weather seems to be reflected in a corresponding decrease in evolution rate. The theoretical calculation assumed the forging to be an infinite cylinder; in practice, end losses would disturb the theoretical radial diffusion, and the agreement between theory and practice appears reasonable, but no satisfactory reason has been found for the initial delay.

DISCUSSION

Discontinuities in the graph of temperature against hydrogen permeation through a diaphragm have been noted by earlier workers. For example Ham and Rast,[11] working with nearly pure iron, found anomalous permeation at temperatures of 117–315° C, and this they attributed to a hitherto undetected transformation varying with the carbon content. Similarly Chang and Bennett,[12] working with iron alloyed with chromium, nickel, or molybdenum, found anomalous permeability developing slowly at temperatures below 400° C in Armco iron, and Fe–Ni alloys, and this was attributed to a change in the mechanism of permeation, the rate being controlled by diffusion at higher temperatures but by surface processes as the temperature fell to the 300–400° C range.

On the other hand, Bennek and Klotzbach found a linear relationship between $1/T$ and log P down to 300° C for several steels, and Hobson found no anomaly in the permeability of 3%Cr–Mo steel down to 140° C.[13]

Since the diffusion constants now calculated from rates of evolution also involve one surface process, it is possible that the anomalous behaviour below about 125° C is due to some change in the mechanism of hydrogen release at the surface. On the other hand it is also possible that the anomalies noted here, and by other workers, are due to a change in the mechanism of diffusion within the metal, and it is difficult to formulate an experiment which would decide which interpretation is correct. From a practical point of view however, there is no doubt that the rate of loss of hydrogen is seriously altered whatever the ultimate cause.

Alloy steel billets are frequently cooled in pits to retard their cooling rate, the object being to prevent the formation of hairline cracks. There is no doubt that the slow cooling allows the escape of a considerable proportion of the hydrogen originally present, and the relaxation of transformation stresses is also probably a factor of importance. The diffusion experiments show that the great reduction in diffusion rate below 100° C makes the continuation of slow cooling below this temperature of little value in reducing hydrogen content. Similar considerations apply to the calculation of the effectiveness of hydrogen-removal cycles for large forgings.

On the other hand, when sampling steel for hydrogen analyses it is evident that for small specimens of about ½ in. dia., serious losses occur in a few hours at room temperature, in a few minutes at 100° C, and in a few seconds at 200° C. The importance of a rapid quench into cold water when using the chill mould notched-pencil technique is therefore emphasized. The very low rates at −78° C mean that small specimens can be stored without serious loss for several days, and that the hydrogen content of larger pieces with sections of 2 in. or more can be preserved almost unchanged for several months.

The very low diffusion rates in the 14%Cr steel are supported by the observation of Chang and Bennett that permeation in an iron + 4%Cr alloy was reduced to one tenth of the rate for iron alone, and it seems that the presence of chromium causes a great reduction in the rate of diffusion of hydrogen in iron. The experimental results on the 3%Cr–Mo steels add supporting evidence. The high-chromium steels, though ferritic, are not normally considered to be susceptible to the defects attributed to hydrogen, and it seems possible that this may be due to the much slower hydrogen diffusion rates in these steels. It would follow that any induction period before the onset of cracking would also be much longer and it may well be that flaws do not develop until long after inspection.

Acknowledgments

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Experience with Sinter Burden in Swedish Blast-furnaces

By Ulf Notini

SYNOPSIS

Most Swedish blast-furnaces working with coke are using 100% sinter, and many of them self-fluxing sinter. The paper analyses the results obtained by these processes. Coke consumption can be reduced by 20–25% with sinter because of its improved reducibility, and a fusion zone richer in iron and a higher blast temperature can be obtained. The production of self-fluxing sinter gives a further saving of 10–15%. At the same time, this method leads to a considerable increase of output, amounting to as much as 250% for charcoal furnaces and 100% for others. However, the use of sinter may produce an increased tendency for the charge to hang, leading to slips.

The advantages offered by the use of self-fluxing sinter are so significant in the author's opinion that it is worth while grinding, concentrating, and sintering the ore, even if the beneficiation does not increase the iron content in the burden appreciably. 1545

THE FIRST SINTER PLANT in Sweden was built in 1915, and during the following 15 years a further 14 plants were erected. Briquettes had already been in use to a relatively large extent since 1903; the proportion in the burden in certain cases was as high as 75%, but the average value for all blast-furnaces was about 25%. By making briquettes of the concentrate it was possible to broaden the ore base and make use of lean ores without increasing the fuel consumption. In fact, the use of briquettes meant an increase in the iron content of the burden and thus a decrease in fuel consumption. However, briquettes were soon replaced by sinter, with its appreciably lower production costs. In 1942 sintering-in of limestone began, and two years later a fully self-fluxing sinter burden was introduced.

Figure 1 shows the development over the last 35 years; it shows that by 1935 the average proportion of sinter in the ore burden was already 80% for all blast-furnaces.

The fact that a great deal of attention has been paid in Sweden in the past to the problems of making and using sinter and that development there has resulted in the widespread use of a 100% self-fluxing sinter burden can be explained by two main factors.

First, the ores from Central Sweden, which were once the exclusive basis of the Swedish iron industry, are mainly dense magnetites that are often difficult to reduce. On the other hand, these ores are usually easy to concentrate, and, after only moderate crushing, give concentrates containing 60–65% iron. These concentrates which are rich in magnetite can be sintered at a high rate of output to produce an easily reducible, porous sinter with a high degree of oxidation and satisfactory mechanical strength. The limestone addition necessary for a self-fluxing burden can also be easily sintered in. With some ores, however, so much crushing is required to separate the ore particles from the gangue that pelletizing must be used instead of suction sintering. Pelletizing in its turn requires still finer crushing, which makes possible a concentration of up to about 70% iron. Pellets have a high reduction strength and have recently replaced sinter completely in sponge-iron making by the Wiberg process. Pellets are not used in Sweden for pig-iron production as in some other countries, for example, the U.S.A., where pellets are now used to a considerable extent and with good results for this purpose.

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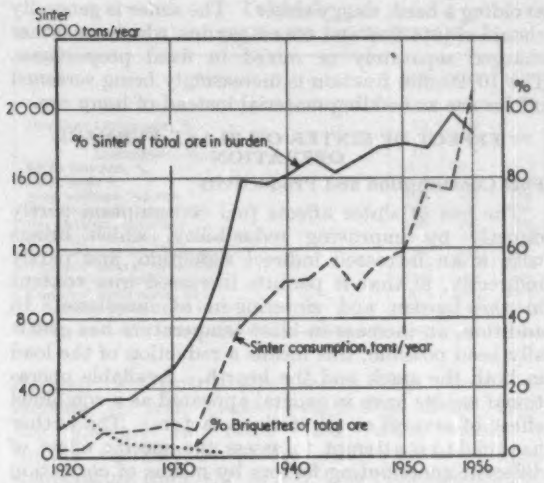

Fig. 1—Sinter in burden and total sinter consumption

Trials have been made in both blast-furnaces and electric smelting furnaces with large-diameter dense pellets of the type used as ore feed in steelmaking furnaces and as raw material for sponge-iron production. However, their use resulted in an increase in coke consumption.

The second reason for Swedish interest in the development of sinter was the fact that Sweden has no domestic resources of coking coal. Charcoal, which earlier was the chief fuel for producing pig iron, has become more and more expensive owing to increasing wages and greater competition from the paper-pulp industry, and can now only be used to a modest extent for pig iron of especially high quality.

The use of briquettes (and later of sinter) began at the charcoal furnaces, largely owing to the ore situation at first, but later because of the increasingly greater need to save charcoal. Figure 2 shows how the proportion of briquettes progressively decreased, until in 1935 they practically disappeared from the burden. The proportion of sinter increased rather

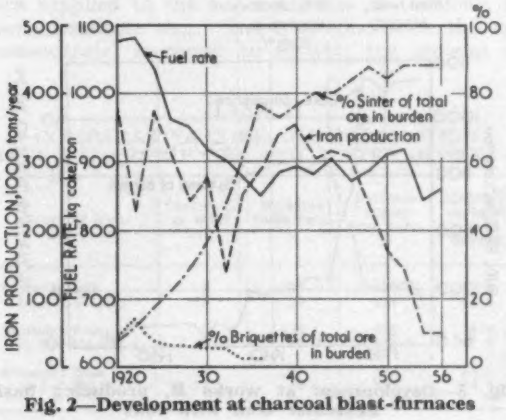

Fig. 2—Development at charcoal blast-furnaces

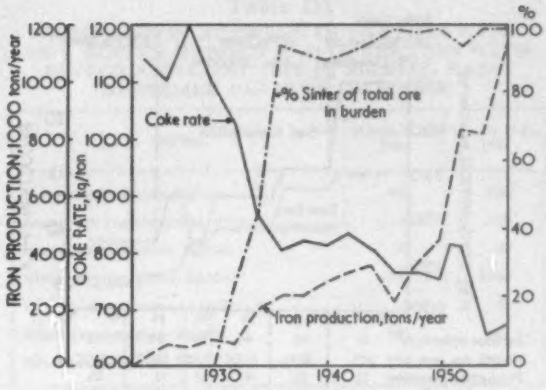

Fig. 3—Development at coke blast-furnaces

sharply to 75% of the total ore in 1936, and thereafter it rose more gradually to a value between 85% and 90%. At the same time charcoal consumption decreased from about 975 kg of coke per ton of pig iron (1 m³ charcoal = 160 kg coke) to 800–850 kg/ton. Production of charcoal pig iron decreased considerably during this period; it is now produced to any extent only in out-of-date blast-furnaces, because the larger, more modern units have gone over in turn to coke. Fluctuations in fuel consumption after 1935 are mainly due to variations in the quality of the charcoal. In general quality has decreased as a result of increased consumption of furnace charcoal at the expense of charcoal from piles.

Figure 3 shows that sinter was not used in coke blast-furnaces until after 1930, but that subsequent development was very fast, so that by 1935 90% of the burden was sinter. From 1943, a further increase began as a result of efforts to obtain a 100% self-fluxing sinter burden. Coke consumption decreased from 1100–1150 kg/ton with lump ore to about 800 kg during 1935–1944 with about 90% sinter, and showed a further decrease with sintering-in of limestone. It must be emphasized, however, that the fuel saving shown in Fig. 3 is not solely due to increased use of sinter; it is the combined result of this and several other factors, such as larger furnace units, reduced proportion of foundry and acid Bessemer pig iron (whose fuel requirements are heavy), higher iron content in the burden, and higher air-blast temperature. The increased coke consumption in 1951–1952 was due, for example, to a temporary increase in the proportion of foundry pig iron, when a new large production unit was taken into service. The large decrease in 1953 and 1954 was connected with this unit being changed over to the production of basic Bessemer pig iron.

THE MANUFACTURE OF SINTER

All sinter is produced in pans, mainly of the Greenawalt type. A vacuum of 1000–1500 mm is used. Sintering time is 25–40 min, depending on the depth of the sinter bed and the particle size of the ore. The corresponding daily production per square metre of grate area is 12–24 tons. A porous sinter with a

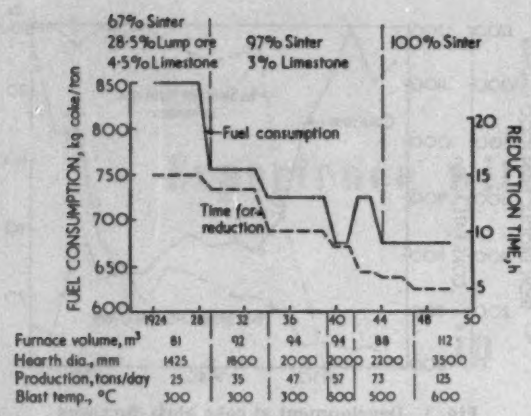
67% Sinter
28·5% Lump ore
4·5% Limestone
97% Sinter
3% Limestone
100% Sinter
FUEL CONSUMPTION, kg coke/ton
REDUCTION TIME, h
Fuel consumption
Time for reduction
Furnace volume, m³ 81 92 94 94 88 112
Hearth dia., mm 1425 1800 2000 2000 2200 3500
Production, tons/day 25 35 47 57 73 125
Blast temp., °C 300 300 300 600 500 600

Fig. 4—Development at works *A*, producing open-hearth iron with charcoal

high degree of oxidation, good reducibility, and good mechanical strength is aimed at; desulphurization should also be good. The content of constituents which are difficult to reduce (e.g. iron silicates) should be kept to a minimum.

Four factors are involved in attaining this:

(i) *Good blending* of the constituents of the sinter mixture
(ii) *Loose and even charging* of the pans
(iii) *Suitable particle size.* Maximum size of the ore particles is normally 3 mm; the proportion of particles below 200 mesh, on the other hand, should be as low as possible, and preferably not exceeding 10%
(iv) *Low fuel consumption*, which implies relatively fine-grain coke breeze. The maximum size should not exceed 3 mm, which is often difficult to obtain in a rotary mill despite reduction of the water content of the coke breeze to about 5%. Rod mills have shown themselves to be the best for this purpose: they give a relatively even particle distribution, and a maximum size of 2–3 mm can be obtained. The amount of coke breeze in the sinter mixture is 3–5%, which corresponds to 35–60% kg per ton of sinter used in the blast-furnace.

Sintering-in of limestone has been found to take place without extra fuel; indeed in most cases it has been possible to reduce the amount of fuel. The addition of limestone has as a rule increased production, as the bed becomes more porous. There has been increased oxidation of the sinter in many cases. The addition of limestone reduces the risk of iron silicate being formed. Desulphurization is not adversely affected, provided that the limestone is ground sufficiently finely.

Frequent routine checks are made on the sinter; these are chiefly to ascertain the basicity (CaO/SiO_2 ratio) and the moisture content in the mixture.

In Swedish practice, all sinter material below 5–10 mm is screened off in the sinter plant and is returned to the mixture; the quantity of returns amounts to 15–20%. This relatively large amount is partly due to the use of lean blast-furnace gas for ignition; this takes place slowly, and so sintering of the upper surface layer is incomplete. Moreover, the method used, as already mentioned, aims at avoiding a hard, slaggy sinter. The sinter is generally classified into fine and coarse grades, which are either charged separately or mixed in fixed proportions. The 10–20-mm fraction is increasingly being screened off for use as bedding material instead of lump ore.

EFFECT OF SINTER ON BLAST-FURNACE OPERATION

Fuel Consumption and Productivity

The use of sinter affects fuel consumption partly directly by improving reducibility, which brings with it an increased indirect reduction, and partly indirectly, in that it permits increased iron content in the burden and sintering-in of limestone. In addition, an increase in blast temperature has generally been possible; this means a reduction of the load in both the stack and the hearth. Available operational results have in general appeared as a combined effect of several or all of these factors. The author has made no attempt to assess the specific effect of different contributing factors by means of correction factors, as views on the magnitude of such factors diverge appreciably. Furthermore, during the gradual changeover from lump ore to self-fluxing sinter, changes have been made in the shape and dimensions of blast-furnaces, in the charging arrangements, etc. Classification of the product has in many cases been introduced, and there have been successive improvements in the quality of the sinter. It is impossible to evaluate the effect of all these changes.

Developments at two blast-furnaces are shown in Figs. 4 and 5; this is further illustrated by results from a number of other blast-furnaces.

One example shown in Fig. 4 is taken from ironworks *A*, making open-hearth pig iron with charcoal. Fuel consumption is stated in terms of the equivalent amount of coke (1 m³ charcoal = 160 kg coke). As a measure of the production, the average time in hours taken for the material to pass through the blast-furnace ('reduction time') has been chosen. An increase in the proportion of sinter in 1929 from 67% to 97% resulted in a decrease in fuel consumption corresponding to almost 100 kg of coke per ton. In addition to the improved reducibility of the

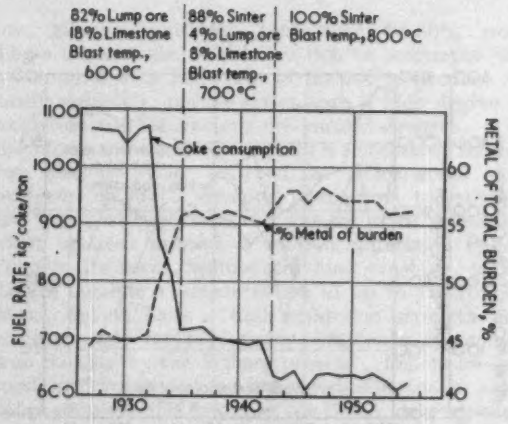

Fig. 5—Development at works *B*, producing basic Bessemer iron with coke

Table I

PRODUCTION RATE OF WORKS *B*

Year	1930	1940	1950
Burden: Lump ore, %	82	4	...
Sinter, %	...	88	100
Limestone, %	18	8	...
Fe in burden, %	46·5	50·5	53·3
Fe in ore, %	56·5	61·5	61·5
Slag volume, kg/ton	900	450	450
Blast temperature, ° C	600	700	800
Production, tons/day	100	160	430
Tons/m³ working volume, day	0·9	1·2	1·7
Relative production rate	100	133	189
Tons/m² hearth area, day	18·9	21·2	27·0
Relative production rate	100	112	149
Tons/m² bosh area, day	8·4	12·1	19·5
Relative production rate	100	143	232

burden, a contributory factor has been an increase in iron content of 2·5%. Since 1934, the charcoal has been dried, which meant a further decrease of 30 kg. An increase of blast temperature from 300° to 500° C in 1940 reduced fuel consumption by an amount corresponding to 50 kg of coke per ton. The increase by about the same amount during 1942–1943 can partly be explained by poorer charcoal, but it might, however, be connected primarily with a decrease of more than 30% in the reduction time. Imperfectly reduced sinter descends into the bosh, which means increased direct reduction there. As a result of the introduction of self-fluxing burden in 1944 and of improvements in sinter quality in other ways, it was possible not only to reduce fuel consumption to the earlier lower level, but also to lower the reduction time still further by about 20%. A contributory factor here was the increase of 100° C in the blast temperature, which occurred at the same time. During test periods, the reduction time could be decreased to under 4 h without an increase in fuel consumption, which proves the good reducibility of the self-fluxing sinter.

The next example (Fig. 5) shows the development at a blast-furnace plant (works *B*) producing basic Bessemer iron using coke. With a burden of dense, hard lump ore of 56%Fe, about 900 kg of slag, and a blast temperature of about 600° C, coke consumption was 1060 kg. In 1934 sinter was first used and from 1935 to 1942 the proportion of sinter went up to an average of 88%. About 50% of the requisite CaO was supplied to the sinter mixture in the form of basic Bessemer slag. The iron content in the ore (concentrate) increased to 61·5%; the amount of

Table II

COMPARATIVE COKE AND PRODUCTION RATE WITH LUMP ORE AND SINTER (WORKS *C*)

Grade of Iron	Sinter, % of total ore	Relative Coke Rate, %	Relative Production Rate, %	Metal, % of total ore in burden
Open-hearth iron (1·0 %Si)	0	100	100	57·5
	85	79	185	61·5
Foundry iron (1·5–2·5% Si)	0	100	100	55·5
	78	77	188	62·0
Foundry iron (2·5–3·5% Si)	0	100	100	58·2
	75	80	155	62·6

Table III

COMPARISON BETWEEN OPERATION WITH 100% SINTER BURDEN AND OPERATION WITH SINTER AND LUMP ORE IN MAKING BASIC BESSEMER PIG IRON (WORKS *D*)

Period	Weeks 1–26, 1956	Weeks 1–26, 1957
Coke consumption, kg/ton	642	688
Lump ore consumption, kg/ton	...	110
Scrap consumption, kg/ton	34	23
Sinter consumption, kg/ton	1832	1685
Degree of oxidation of sinter, %	96	95
Blast-furnace slag, kg/ton	501	501
Blast temperature, ° C	874	884

blast-furnace slag decreased to about 450 kg; and the blast temperature was increased on an average by about 100° C. All these steps resulted in reducing coke consumption to about 700 kg. From 1943, all limestone was sintered-in, and also the remaining proportion of lump ore (manganese ore) from 1944. Rebuilding the hot-blast stoves permitted an increase of the blast temperature to about 800° C. As a result, a further reduction in the coke consumption by about 60–70 kg to 630–640 kg/ton was obtained.

Production rose appreciably during this period (Table I); it increased from 0·9 ton/m³ of effective furnace volume using lump ore to 1·7 tons/m³ with 100% self-fluxing sinter, i.e. by 89%.

Table II gives the result from an earlier period consisting of several years' operation using sinter in the burden at works *C*. The sinter was produced without addition of limestone. The blast temperature when operating with sinter was on an average about 50° C higher than during the comparative period with lump ore alone. The metal yield increased 4–5% as a result of the higher iron content of the concentrate. No other changes were made. Coke consumption decreased by 20–23% with a simultaneous increase in production of 55–58%.

It has been found in Sweden that even small quantities of lump ore in the burden have an appreciable detrimental effect. The ores available are only in exceptional cases so easily reducible as to be suitable for use in lump form. This is an important reason for lump ore being replaced by sinter as bed material in the sinter plant. Table III from works *D* serves to confirm this interpretation. Although only 6% of lump ore was used during the first half of 1957, coke consumption was 46 kg higher than in the comparative period in 1956. The lower (1%) oxidation of the sinter also partly contributed to this.

The opinion is often held outside Sweden that it does not pay to exceed a certain relatively low percentage of sinter in the burden. The reason for this may be that it is based on experience with sinter that is hard and slaggy, often containing a large amount of iron silicate, and is thus not so easy to reduce as that normally produced in Sweden. Moreover, the lump ore used is also more easily reduced than the Swedish ores. The difference in reducibility

between sinter and lump ores would in this case be insignificant. Swedish opinion appears to be completely shared, however, by the Russians, who in their large modern blast-furnaces now use a 100% self-fluxing sinter burden with very good results.

It has already been emphasized that sintering-in limestone with the intention of obtaining a self-fluxing sinter obviously reduces the fuel consumption.

Works *A* shows a reduction corresponding to 65 kg/ton of iron. According to Fig. 4, the same decrease was obtained at works *B*. At works *D*, a lowering of 125–150 kg of coke per ton of iron was found, with an increase in the CaO/SiO_2 ratio in the sinter from 1·0 to 1·5. The latter value means that all the required limestone was sintered-in. The degree of oxidation of the sinter increased by 2% (from about 93% to 95%). This increase may to a large extent be attributed to the increased addition of limestone. Part of the large reduction in fuel consumption in the last instance, however, is probably due to the simultaneous increase of the proportion of sinter from 80% to 90%.

In experimental runs, works *C* reduced coke consumption in the same large proportion, namely 100 kg/ton in the manufacture of foundry pig iron and over 125 kg/ton with open-hearth pig iron. It is of special interest that these results were obtained with sintering-in only half the total limestone, which amounts to 20% of the burden. The fact that coke savings are less with high-silicon pig iron is explicable because direct reduction of silicon requires so much coke in the hearth that there is an excess of gas in the upper part of the blast-furnace. The better reducibility of the burden cannot be fully utilized. This is reflected not only in an increased CO/CO_2 ratio but also in higher top-gas temperature.

The reasons for the reduction in coke consumption with the use of self-fluxing sinter can be summarized as follows:

(i) No heat is required for burning limestone in the blast-furnace

(ii) The height of the zone of indirect reduction therefore increases

(iii) The reducing action of the gas in the shaft is increased, as it is not diluted by CO_2 from the limestone

(iv) The sintered-in limestone increases the reducibility as a high degree of oxidation is obtained more easily and there is less risk of iron silicate formation.

Hanging and Scaffold Formation

It is not yet fully established that interference in the operation of the furnace resulting from hanging and scaffold formation is increased with sinter burdens. It is widely held that interference of this kind occurs slightly more often than with lump-ore burdens. Several factors, individually or in different combinations, may cause interference of this nature; only those directly connected with the use of sinter instead of lump ore will be considered in the paper. In discussing hanging, a distinction should be made between that occurring in the upper part of the blast-furnace and that occurring at a level immediately above the tuyeres, but the author is well aware that such a distinction is often difficult to make.

Hanging in the Stack

Current opinion appears to be that hanging occurs either with coke of low mechanical strength or with a fine-grained burden. Resistance to gas flow increases in the stock and in extreme cases the flow may almost completely cease, movement of the stock decreasing or ceasing accordingly. This means that there is an increased likelihood of the sinter sticking together or fastening on to the stack walls. The cause of scaffolds should therefore be sought primarily in hanging. On the other hand, when scaffolding occurs, the risk of hanging increases, and so there may be some interaction between these phenomena. A laminated build-up of scaffold has been observed in a number of cases, and this may be interpreted as support for this theory. The possibility of the ore (sinter) lumps sticking together should increase as the volume of coke is decreased in proportion to the burden.

In the light of the above reasoning, a greater tendency for hanging and scaffolding to occur with sinter burdens may be explained thus:

(i) Sinter has a lower bulk density than lump ore and, moreover, since the use of sinter means a saving in coke, the coke takes up a proportionately smaller volume. With charcoal blast-furnaces, where the diluting effect of the fuel is many times greater, hanging occurs less frequently

(ii) Sinter of the type desired in Sweden generally has a lower reduction strength than lump ore. Even if fine-grained material is screened off when the furnace is charged, so that a sinter burden as a rule contains a smaller amount of fine-grained and potentially obstructive materials than a lump-ore burden, the sinter can disintegrate to such a degree during indirect reduction that the conditions become reversed lower down in the blast-furnace

(iii) With a self-fluxing sinter burden, indirect reduction starts only a few feet down the shaft. Owing to the good reducibility of the sinter, an appreciable quantity of sponge iron is formed at an early stage. Sponge iron has a marked tendency to stick at about 1000° C. Investigation of scaffolds has also shown that they consist to a large extent of sponge iron. Scaffolds are especially likely to occur when a large quantity of fine-grained and easily reducible material gets out to the stack wall. As this material moves downwards very slowly, complete indirect reduction can take place to sponge iron below 1000° C, and this sticks to the wall

(iv) Sponge iron increases the catalytic carbon deposition, and it is thought likely that deposited carbon can contribute to hanging.

Hanging in the Lower Part of the Blast-furnace

A common cause of this type of hanging is the occurrence of viscous basic slag at a critical level. A higher reduction of SiO_2 in the slag increases the slag basicity more as the slag volume decreases. Increased risk of hanging can thus arise from the use of sinter. The relatively smaller coke volume might also have some influence in this case.

However, a self-fluxing sinter burden is more homogeneous and has more constant chemical and physical properties, which has an opposite effect. It seems to be possible as a rule to use higher blast temperatures (900–1000° C) than with lump ore, which probably must be ascribed to this fact.

Behaviour of Nitrogen in 3% Silicon Iron

By R. E. Fryxell, Ph.D., N. Galitzine, M.Sc., and F. S. Gardner, Sc.D.

SYNOPSIS

Studies of the reactions of nitrogen in a 3% Si iron alloy are described. The results are interpreted in terms of the solution/precipitation equilibrium of silicon nitride, Si_3N_4. For this work, a revaluation of chemical analysis methods has been essential. 1499

INTRODUCTION

IN RECENT YEARS, interest in the reactions of nitrogen in ferrous alloys has considerably increased. Many of the papers which have appeared have been specifically concerned with the effect of silicon as an alloying element on the solid solubility of nitrogen: either (*a*) the equilibrium between solid solution and nitrogen gas or (*b*) the equilibrium between solid solution and precipitated nitride.[1–5] In 1956, Sloman first reported the isolation of silicon nitride from a commercial 4%Si iron alloy.[6] This observation, which confirmed earlier results obtained in this laboratory, has prompted the preparation of the present report which describes studies of the reactions of nitrogen in electrical sheet steel containing nominally 3·25% silicon.

With the exception of Sloman, none of the authors cited has discussed the difficulties of obtaining reliable chemical analyses of silicon–iron alloys. Although the present work has led to some results of metallurgical significance, one of the prime objects of this report is to focus attention on the problems of analysis. Briefly, most routine determinations of nitrogen in ferrous alloys are made by some form of an acid hydrolysis method. It is often assumed that the results obtained represent the total nitrogen in the specimen. That this assumption is not always valid for many ferrous alloys is well known to chemists.[7, 8] Kempf and Abresch[9] and Beeghly[10] have presented especially provocative studies which show that the fraction of nitrogen available to the acid hydrolysis method depends on the metallurgical history of the specimen as well as on the conditions of chemical attack. Experiments herein described show that the same is true for iron containing 3·25% silicon. It is suggested that this observation requires a re-evaluation of some of the work cited above.

In the authors' laboratory, the vacuum fusion and hydrochloric acid evolution methods have been extensively compared. Since each has proved itself capable of a precision of about 0·0003% (σ), small discrepancies can be detected and studied even at low total-nitrogen levels. The approach in these experiments has not been to remove the discrepancies, but rather to attempt to understand them. Nitrogen obtained by the evolution method is referred to as 'acid-soluble' nitrogen.

There are three conclusions to be drawn from this work. (1) The vacuum fusion method provides an accurate measurement of the total nitrogen content, independent of the metallurgical history of the specimen. (2) The hydrochloric acid evolution method measures variable fractions of the total nitrogen, dependent on the temperature of heat-treatment of the steel. (3) The nitrogen measured by the evolution method is in solid solution, and that not measured exists in a precipitated silicon nitride.

EXPERIMENTAL DETAILS

Except where noted, the experiments were conducted with several heats of a commercial grade of silicon iron processed to 0·012-in. sheet. These all behaved similarly and had the following nominal composition:

Silicon	3·25%
Manganese	0·05%
Copper	0·08%
Aluminium	0·002%
Oxygen	0·01%
Sulphur	0·015%
Carbon	0·02% or lower
Nitrogen	0·0025%.

As will be seen, a knowledge of time and temperature of heat-treatments is important for correlation with nitrogen chemistry. These heat treatments were performed in various atmospheres and followed by a water quench.

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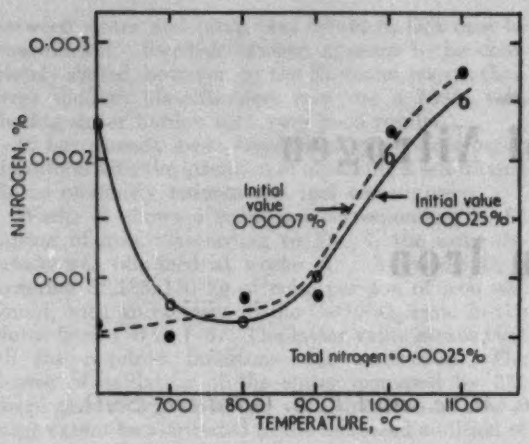

Fig. 1—Acid-soluble nitrogen *v.* quench temperature

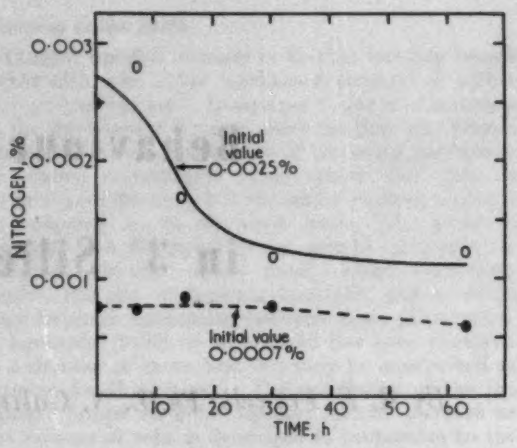

Fig. 2—Acid-soluble nitrogen *v.* time at 600° C

The vacuum fusion method as operated in this laboratory is adequately described in two publications.[11, 12] Briefly, it consists of melting the sample in a graphite crucible in a vacuum, and fractionating the gases pumped off. Nitrogen is the residual after all others are frozen out in a trap cooled by liquid nitrogen. All measurements are manometric. The blank is invariably less than 0·0002% and is ignored.

The hydrochloric acid evolution method is essentially the same as described by Beeghly[13] with the exception that 5 ml of 4% sodium fluoride is added to the 20 ml of 1 : 1 hydrochloric acid for dissolving the sample. The sample solution is rendered alkaline, ammonia removed by steam distillation and determined photometrically at 400 mμ after colour development with Nessler's reagent.

Two methods have been used for the separation of inclusions:

(1) A 4–5-g steel sample is dissolved in 200 ml of 10% aqueous ammonium persulphate in a 600-ml beaker, with only occasional stirring in the first three hours, then continuously until dissolution is complete. The residue is first centrifuged in a 200-ml centrifuge bottle, the major part of the supernatant liquid drawn out from the bottle, and the remaining solution with residue centrifuged in 5-ml centrifuge tubes. The residue is washed several times with water, then with acetone and ether. An advantage of this method lies in the fact that both iron and silicon are kept in solution.

(2) A 4–5-g steel sample is dissolved in a bromine–methyl acetate solution as originally suggested by Beeghly.[14] Much of the silicon is converted to amorphous silica which must be subsequently removed by hydrofluoric acid. Fortunately, silicon nitride resists this treatment.[15]

X-ray identification of inclusions has been made by Debye-Scherrer powder photograms.

RESULTS AND DISCUSSION

I. Acid-soluble Nitrogen *v.* Quenching Temperature

It was apparent early in this investigation that the acid-soluble nitrogen content was somehow determined by the history of heat-treatments. Consequently, a series of specimens was prepared, each heated at a different temperature for 20 min. Two types of initial material were used: (*a*) total and acid-soluble nitrogen equal at the level of 0·0025%; (*b*) total nitrogen = 0·0025%, but acid-soluble nitrogen = 0·0007%. Figure 1 shows composite curves of the data obtained with several heats of each of the above types. Total nitrogen was unaffected whether the atmosphere was argon or 99%N_2 : 1%H_2. Consequently, the acid-soluble nitrogen values represent a reaction which is strictly internal. At temperatures of 700° C and above, it is apparent that an equilibrium property is being measured, since the same results are obtained whether the initial acid-soluble nitrogen is equal to the total, or much less. At lower temperatures, the two curves are significantly different, sug-

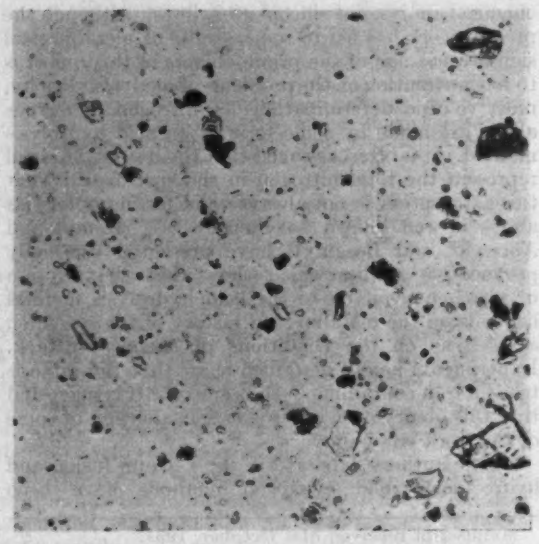

Fig. 3—Photomicrograph of inclusions separated from commercial 3% Si iron × 400

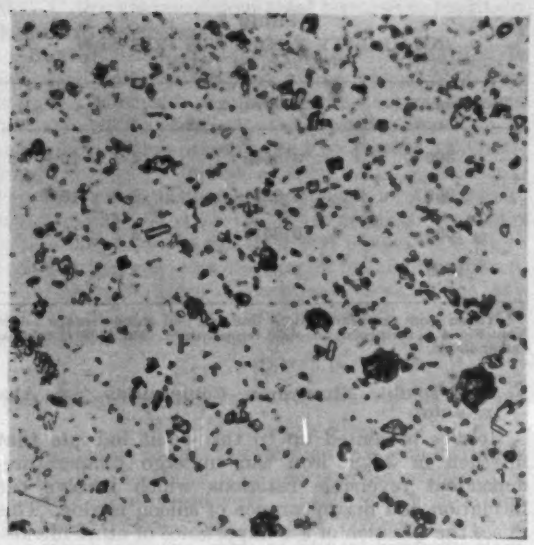

Fig. 4—Photomicrograph of synthetic silicon nitride × 400

gesting that a 20-min heat-treatment is insufficient to drive the nitrogen reactions to equilibrium. This point is discussed in detail below.

Variations in the concentration of carbon in the range 0·003–0·020% were without effect on the behaviour described in Fig. 1.

II. Acid-soluble Nitrogen *v.* Time of Heat-treatment

Since Fig. 1 indicates that equilibrium is not achieved in 20 min at temperatures below 700° C, a separate series of heat-treatments at 600° C in argon

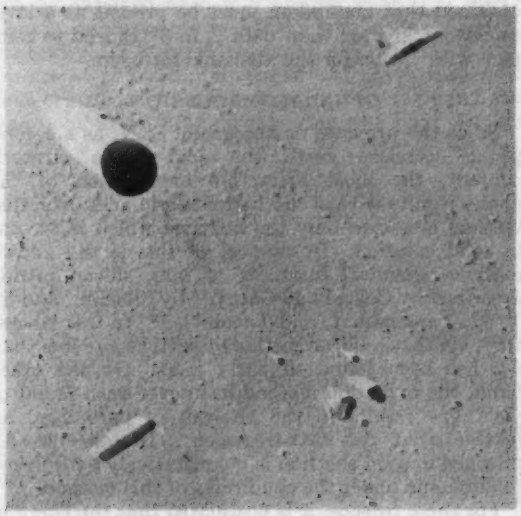

Fig. 5—Electron-micrograph of inclusions separated from commercial 3% Si iron. On plastic substrate, shadow cast with chromium. Polystyrene calibration sphere × 20,000

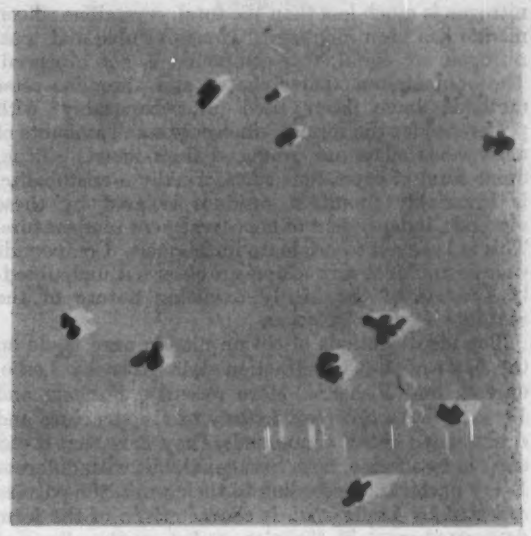

Fig. 6—Electron-micrograph of inclusions separated from nitrided 3% Si iron. On plastic substrate, shadow cast with chromium × 20,000

were performed, with various times up to 63 h. Results are given in Fig. 2 for both types of starting material. These curves show a trend towards a *low* acid-soluble nitrogen content. Thus, the dotted line in Fig. 1 approximates to the equilibrium condition in the region of 600° C. Vacuum fusion analyses of the samples described by Fig. 2 indicated no significant loss of total nitrogen even after 63-h heat-treatment.

A few experiments were performed with 5-min heat-treatments for both types of starting material. Using the dotted curve in Fig. 1 as the criterion, equilibrium was achieved at temperatures of 900° C and above. At 800° C partial reaction took place; at lower temperatures, no measurable reaction.

III. Reversibility of Acid-soluble Nitrogen: Thermal Cycling Between 800° and 1100° C

The fact that the two curves in Fig. 1 essentially coincide above 700° C is good evidence that an equilibrium property is being measured. Further support is found in two experiments which demonstrate the reversibility of these internal nitrogen reactions.

(i) A series of samples typified by the solid curve in Fig. 1 were heat-treated for 20 min at 1100° C. All exhibited acid-soluble nitrogen equal to the total, independent of prior heat-treatments which had ranged from 600° to 1000° C

(ii) Several strips of steel were heat-treated alternately at 800° and 1100° C through two cycles. Samples were reserved for analysis after each 20-min treatment. For both the first and second treatments at 800° C, the acid-soluble nitrogen was found to be low, as predicted from Fig. 1. For the 1100° C treatments, acid-soluble and total nitrogen were equal. Thus, a reversibility was demonstrated, which persisted through two heating cycles.

IV. Acid-soluble Nitrogen *v.* Extracted Silicon Nitride

Inclusions have been separated from a large number of samples. Whenever the acid-soluble

nitrogen is much less than the total, crystalline silicon nitride has been identified. If acid-soluble and total nitrogen are equal, this compound is not observed. The ammonium persulphate and bromine–ester methods have been used interchangeably with preference for the former, since only small amounts of amorphous silica are produced from matrix silicon. Some form of crystalline silica, usually α-cristobalite, is invariably found in residues isolated by these methods, independent of heat-treatment temperature. This is believed to originate in the melt. Compounds such as sulphides very seldom are observed, undoubtedly because of the highly oxidizing nature of the reagents used for isolation.

The identifications of silicon nitride were made on the basis of X-ray diffraction data given by Leslie, Carroll, and Fisher.[17] More recently, Forgeng and Decker[18] have reported a study of the structure and composition of this compound. They show that it can exist in two forms, both hexagonal, but with different X-ray patterns. According to their work, the pattern reported by Leslie *et al.* is characteristic of the form designated as α-Si_3N_4 with a few weaker lines of β-Si_3N_4.

In the present work, silicon nitride separated from commercial 3%Si iron has invariably given X-ray patterns essentially identical in both intensities and *d* values with that given by Leslie *et al.*[17] Consequently, it is believed that the nitride identified is essentially α-Si_3N_4. The discussion below is based on this belief.

Spectrographic analysis of many inclusion samples showed only very small amounts of iron and impurity metals. The absence of iron does not lend support to the supposition of Leak, Thomas, and Leak[4] that the precipitated compound is a complex iron nitride containing silicon.

Visual identification of silicon nitride has also been made. Figures 3 and 4 are photomicrographs (× 400) respectively of a typical silicon nitride extraction and a synthetic sample furnished by W. D. Forgeng. Since many of the particles are too small for resolution with the optical microscope, electron-micrographs were taken at × 20,000. Figure 5 shows inclusions as separated from the same sample used for Fig. 3. Similarly, Fig. 6 shows inclusions separated from a specially nitrided silicon iron. X-ray diffraction indicated this specimen to be pure silicon nitride. (Crystalline silica was removed by treatment with hydrofluoric acid.)

In Fig. 6 most of the particles are rod-shaped crystals in the range of 0·2 μ. (The clustering probably occurs during handling of the inclusion specimen and does not indicate this distribution of particles in the metal matrix.) If this shape is taken as characteristic of silicon nitride, Figs. 3 and 5 give visual evidence of the presence of this compound in the inclusions from commercial silicon iron. Many of the particles in Figs. 3 and 4 do not exhibit the rod shape, but these may be either too small or clusters of small silicon nitride particles. A few of the largest particles in Fig. 3 are probably crystalline silica which is usually identified in inclusions separated from silicon iron. No attempt was made to purify this specimen.

Table I
SOLUBILITY PRODUCTS FOR Si_3N_4 IN 3·25% Si IRON

Temperature, °C	N (dissolved), %*	$K_{S.P.}$
800	0·0006	$4·5 \times 10^{-12}$
900	0·0011	$5·0 \times 10^{-11}$
1000	0·0019	$4·5 \times 10^{-10}$
1100	0·0029	$2·4 \times 10^{-9}$

* Taken from the best straight line in a plot of log average values from Fig. 1 *v.* reciprocal absolute temperature. The 1100° C value is extrapolated.

V. Acid-soluble Nitrogen *v.* Composition (e.g. Aluminium)

Results presented up to this point indicate that nitrogen in 3%Si iron can undergo temperature-dependent reversible reactions which involve the formation and disappearance of silicon nitride. This raises the question of the importance of other nitride-forming elements in affecting these reactions.

Previous workers have studied the content and thermal behaviour of aluminium nitride in low-carbon steel.[19, 20] Their work supports the claim in earlier literature that aluminium nitride is easily and quantitatively hydrolyzed by dilute mineral acids.

Accordingly, an experiment similar to Experiment I was performed using an iron-base alloy containing 2·6%Si, 0·34%Al, and 0·004%N. For all heat-treatments from 600° to 1100°C, the acid-soluble and total nitrogen contents agreed within experimental error. Inclusions were separated by the ammonium persulphate method from 800° and 1100°C samples, and aluminium nitride (AlN) identified in both. Silicon nitride was absent.

In certain incidental experiments, evidence has been obtained that aluminium must be present at a level somewhat greater than 0·01% in 3%Si iron to compete with silicon for the available nitrogen.

GENERAL DISCUSSION

Since the presence or absence of Si_3N_4 as a second phase correlates with the acid-soluble nitrogen content, the most attractive explanation of the above results is that the hydrochloric acid evolution method measures only the nitrogen which is present in solid solution. In support of this is the known extreme chemical inertness of bulk silicon nitride described by Collins and Gerby,[15] by Sloman,[6] and by Tyou, Vanstiphout, and Lacomble.[16] In this laboratory, synthetic silicon nitride of particle size less than 5 μ has been found similarly inert. On the other hand, the evolution method has never been found to yield low results in the analysis of pure iron, no matter what the heat-treatment. In other words, nitrogen in solid solution is quantitatively hydrolyzed to ammonia under the conditions of this method.

For these reasons, it is postulated that the curve in Fig. 1 represents the solid solubility of nitrogen in 3% Si iron in equilibrium with Si_3N_4, at least for the intermediate temperature region 800–1000° C. At lower temperatures, equilibrium is difficult to attain; above

1000° C, there is insufficient total nitrogen to maintain the second solid phase.

Although it has been shown by Seybolt[5] that Si_3N_4 is not stable in 3·25%Si iron above 944° C at 1 atm nitrogen pressure, it seems reasonable to assume that the nitrogen in solution at higher temperatures is equivalent to that which would be present at equilibrium nitrogen pressures as long as Si_3N_4 remains. This latter requirement has been met for the present work at 1000° C, since the times required to attain equilibrium between the two solid phases were short enough to prevent loss of nitrogen to the atmosphere.

Insofar as the above assumptions are valid, one may estimate solubility products expressed in terms of weight per cent. These are given in Table I, where

$$K_{S.P.} = [Si]^3[N]^4$$

representing the equilibrium constant for the reaction

$$Si_3N_4 \rightleftharpoons 3Si_{sol.soln.} + 4N_{sol.soln.}$$

From these, the heat of solution of silicon nitride as defined by the above equation may be estimated as 15 kcal/g-atom of nitrogen, considerably higher than the value of 8 kcal given by Leak, Thomas, and Leak[4] and lower than the value of 24 kcal given by Rawlings.[21]

Curves similar to Fig. 1 have been given by Kempf and Abresch[9] and by Beeghly[10] for a wide variety of iron binary alloys containing small amounts of nitrogen.

It would be interesting to estimate solubility products from these curves for various nitrides, but comparisons must be made with caution, since each of these cases involves a different solvent and few activity coefficients are available.

In appraising recent publications from other laboratories on the behavior of nitrogen in silicon iron, the following should be emphasized:

(1) Sloman states that for some samples of 4%Si iron, full nitrogen recovery in chemical analyses cannot be obtained even if a fuming method is used.[6] That is, use of the vacuum fusion method is absolutely imperative if a value for total nitrogen is desired. On the other hand, Turkdogan and Ignatowicz state that the silicon nitride extracted from their samples was soluble in hot acid solutions.[3] They further suggest a subtle difference in this respect between commercial silicon iron and specially prepared material. If this is so, analytical data obtained by a chemical method should be treated with some scepticism.

(2) Turkdogan and Ignatowicz[3] and Seybolt[5] discuss the difficulty of nitriding silicon iron with a N_2–H_2 gas mixture. Consequently, attempts to equilibrate metal specimens with such an atmosphere may not always be successful.

(3) In the course of the present work, a sample of 3·25%Si iron was nitrided in cracked ammonia at 585° C to a level of 0·6% total nitrogen. Most of this nitrogen was found to be acid soluble. However, heat-treatment at a temperature of 700° C or higher reduced the acid-soluble nitrogen to a small fraction of the total. This is remarkably similar to the experience of Leslie, Carroll, and Fisher[17] who state that 3·20%Si iron nitrided at 1200° F required subsequent heat-treatment at 1500° F to produce silicon nitride particles large enough for study. This suggests that the vulnerability of the nitrogen to acid hydrolysis prior to the 700° C heat-treatment may be the result of the existence of a nitride precipitate in very fine particles.

Table II

COMPARISON OF SOLUBILITY DATA FOR NITROGEN IN SILICON IRON IN EQUILIBRIUM WITH Si_3N_4, %

Temperature, °C	Turkdogan and Ignatowicz			Corney and Turkdogan*	Leak, Thomas, and Leak	Present Work
	0·90% Si	1·26% Si	2·83% Si	2·83% Si	2·83% Si	3·25% Si
500	0·0060	0·0017			0·002	
600	0·0120	0·0034	0·0003		0·004	0·0001**
700			0·0009		0·006	0·0003**
800				0·0016	0·009	0·0006
900				0·0019	0·014	0·0011
1000				0·0021	0·018	0·0019

* According to the interpretation suggested in this paper
** Extrapolated

Keeping these points in mind, it appears that an alternate interpretation of Fig. 3 in the paper by Corney and Turkdogan[1] may be made. Seybolt has shown[5] that for 3·3%Si iron, 1 atm nitrogen pressure is sufficient to maintain silicon nitride up to a temperature of 944° C. Conversely, at a temperature below this point, 1 atm of nitrogen must induce pick-up by the alloy with concurrent precipitation of silicon nitride. Although for 2·83%Si iron the critical temperature will be somewhat lower than 944° C, (about 925° C) it is suggested that the data given by Corney and Turkdogan between 705° C and this critical temperature indicate nitrogen solubilities in equilibrium with precipitated silicon nitride. That the curve does indeed represent a solubility function is a fortunate consequence of the authors' use of an acid hydrolysis method which measures only the nitrogen in solid solution. At 705° C and below, extensive nitriding apparently occurred. However, the large amounts of observed nitrogen in the metal may be the result of a particle-size factor as suggested above. Their statement that silicon nitride will not form *above* 705° C is inconsistent with the present work.

If the above interpretation is accepted, a comparison may be made of solubility values in Corney and Turkdogan's Fig. 3 with those obtained in the present work. This comparison is shown in Table II which also gives data obtained by Turkdogan and Ignatowicz[3] and by Leak, Thomas, and Leak.[4]

The reappraised results from Corney and Turkdogan follow in a reasonable sequence those of Turkdogan and Ignatowicz for 2·83% silicon iron, thus lending support to the suggested interpretation. The results of Leak, Thomas, and Leak[4] were obtained using the internal friction method. It is not clear why these are much higher. Turkdogan and Ignatowicz postulate that a metastable nitride may form under conditions of the internal friction experiment.

Acknowledgments

This work has required the aid of specialists in a variety of techniques. The authors are particularly

indebted to R. A. Choiniere for the heat-treatment of metal specimens, to R. G. Hirst for X-ray studies of inclusions, to K. P. Kreis and A. S. Holik for preparation of the photomicrographs, and to A. U. Seybolt for valuable consultation and criticism of the final manuscript.

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Letter to the Editor

Influence of Uniformity on the Oxidation of Alloys

THE IMPORTANCE of the uniformity of an alloy on oxidation behaviour is clearly demonstrated by the following observation. A commercial 0·5% silicon–iron alloy of initial thickness 0·025 in. was polished by removing various thicknesses of the surface, namely 0·003, 0·004, 0·005, and 0·006 in., and eventually with 4/0 emery paper. Although the surfaces were initially identical, the behaviour in pure oxygen at 970° C was markedly different. The different rates of attack are shown in Fig. *A*.

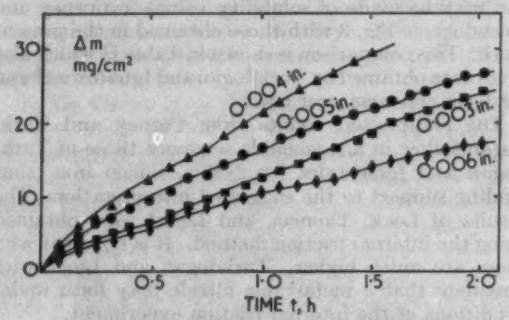

Fig. A—Variation of oxidation behaviour with thickness of initial surface polishing

The observed anomalous behaviour suggests that the alloy was not uniform and this could have arisen in a number of ways. Evidence has been obtained* from chemical analysis of surface oxides and from microscopic examination of the sub-surface layers, that silicon will be depleted in the surface of silicon-steel sheets during annealing unless the furnace atmosphere is suitably controlled. For example, we have calculated from simple thermodynamic considerations that as little as 0·007% moisture in hydrogen at 1000° C could precipitate silica from a steel containing 1 at-%Si. The nature and extent of the silicon depletion would probably depend on the relative rates of inward diffusion of oxygen or outward diffusion of silicon.

We have recently made a full study of high-purity silicon alloys under various oxidizing conditions which will be shortly published.

Department of Metallurgy J. W. Evans
University of Manchester S. K. Chatterji
22nd April, 1958.

*J. M. Camp and C. B. Francis: "The Making, Shaping and Treating of Steels", p. 1307: 1951, 6th edn., Pittsburgh, Pa., United States Steel Corporation.

A New Approach to the Problem of Creep

By J. Glen, B.Sc., A.R.C.S.T., F.I.M.

SYNOPSIS

A number of strain-age-hardening phenomena were observed in high-temperature tensile tests, each being associated with the presence of a particular alloying element. It has now been found that related effects can be detected in the creep curves of various steels and other alloys. These take the form of a sudden deceleration of creep rate over an interval of time and have been called transitions in creep rate. Several transitions usually occur in the creep curves of commercial alloys.

To show up these transitions in creep rate in their true perspective it was found necessary to plot creep data in the form of log strain/log creep-rate curves (strain/rate curves). A family of such curves either at constant stress or at constant temperature forms a regular pattern so that the strain/rate curves of tests at lower stress or temperature can be estimated. By integration the ordinary strain/time creep curves are obtained. In this way accurate extrapolation of creep or rupture tests can be carried out. The results of tests on several manganese steels were used to illustrate the above phenomena. 1492

IN 1910, ANDRADE[1] carried out the first scientific study of the creep of metals. Since that time investigation of the problem of creep has been pursued with ever-increasing vigour as the practical importance of the problem became more urgent. A brief survey of the literature indicates the immensity of the effort expended and the success which has been obtained in the development of new alloys to meet the needs of the engineer. On a purely theoretical basis much less progress has been achieved. This was perhaps only to be expected since until fairly recently no satisfactory theory existed to explain the strength properties even at ordinary temperatures. The advent of the dislocation theory has, however, led to a renewed interest in the more theoretical aspects of the study of strength, but much remains to be done before this theory can be of much help towards a solution of the practical problem of creep.[2]

Because the basic mechanism is unknown, empirical methods are used to study the creep properties of industrial alloys. These methods of necessity involve the use of one or more comparatively short-time creep tests which in the light of experience are considered suitable for the comparison of different materials. The best alloy on this basis is then subjected to more prolonged testing to provide information on which to base working stresses. The author has shown,[3] however, that the order of creep resistance of several steels as measured by a short-time test can be completely altered by changing the stress or temperature of testing. It is thus very difficult to decide which of several materials should be subjected to prolonged testing.

Even the alloys which have already been developed are not always used to full advantage because of uncertainty regarding their true strength under long-time service conditions. This aspect of the subject has been reviewed by Bailey.[4] His paper and the wide discussion which it provoked indicate that as yet no reliable method exists which will indicate the strength in, say, 100,000 hours from tests of much shorter duration. The situation is perhaps better illustrated by an example. In 1946 Tapsell and Ridley[5] reported the results of creep tests of about 5000 h duration on a simple carbon steel. Later[6] the results of more prolonged tests were reported including one of about 70,000 h. The latter results are compared with the original estimate in Fig. 1. As will be noted the extrapolation underestimated the temperature for 0·1% creep whereas it overestimated the temperature for 0·3% creep. What is perhaps more important is the fact that, for the same sample of steel at the same stress, the curve for 0·1% creep is concave upwards whereas at a slightly greater creep strain the curve is concave downwards. Clearly, therefore, extrapolation without some theoretical justification may be seriously in error. In this connection it should be emphasized that the length of a curve in a log-time plot may be very misleading. Thus if test results extend from 1 to 10,000 h only a 25% extrapolation in the length of the log-time curve is required to reach 100,000 h, whereas on a linear scale the extrapolation is no less than 900%.

Similar conclusions apply to rupture testing as was shown recently by the results of many long-time rupture tests on a large variety of steels.[7, 8] As well as emphasizing the danger of extrapolation, these data show that quite a wide scatter is to be expected in the rupture strength of nominally similar material. In the extreme the variation in stress for rupture in, for example, 10,000 h is no less than $\pm$ 25% of the mean rupture strength.

Because of the above difficulties and to minimize the work necessary to develop and prove a new material, the author has attempted a new approach to the problem of creep. This has involved the study of the high-temperature tensile properties of a variety of steels.[9, 10] It was shown that a number of different strain-age-hardening phenomena exist each associated with the presence of a particular alloying element. It has now been found that related effects can be detected in the creep curves of various steels and other alloys. Since a detailed treatment of the subject would be rather lengthy it has been deferred to a later paper. The present paper is limited to a simple statement of the basic concept of this new approach with examples showing its application to the practical problem of extrapolation.

BASIC CONCEPT

The creep resistance of a metal or alloy depends to a considerable extent on the microstructure. For this reason a sample of the metal or alloy in any particular condition of heat-treatment can be considered to have a certain initial creep resistance. This

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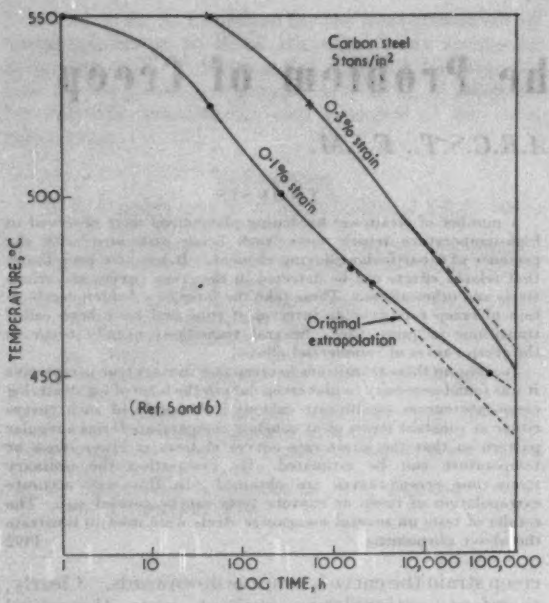

Fig. 1—Iso-strain curves for carbon steel

is low for a pure metal, higher for a simple solid solution and may be very high for an alloy containing a finely dispersed and coherent precipitate.

In pure metals the initial creep resistance comprises the total creep resistance. With most commercial alloys on the other hand the total creep resistance is compounded of two parts: the initial creep resistance and what may be called the latent creep resistance. The latter has no effect initially and only comes into play during the progress of a creep test as a result of the various strain-age-hardening or strain-induced precipitation phenomena mentioned above.

Because fine precipitates and ageing phenomena contribute to the creep resistance a third effect must also be considered. This is simply the overageing or spheroidization of the precipitate and results in a more or less gradual reduction of the creep resistance with increasing time of test.

The shape of a creep curve for a pure metal is essentially simple. Immediately after loading the creep rate is very fast, but it slows down with time until eventually a more or less constant creep rate is obtained. This ends the primary stage of creep. In the secondary stage, the creep rate remains constant, but eventually the third, or final, stage is reached. In this stage the creep rate begins to accelerate and continues to accelerate until fracture takes place. The curve ABC in Fig. 2 is typical. In an alloy showing some latent creep resistance the shape of the creep curve is no longer of the above simple type. Considering an alloy in which only one ageing effect can occur, then initially the creep rate slows down in a manner similar to that of a pure metal. After some time, however, the creep rate decelerates rapidly over an interval of time giving

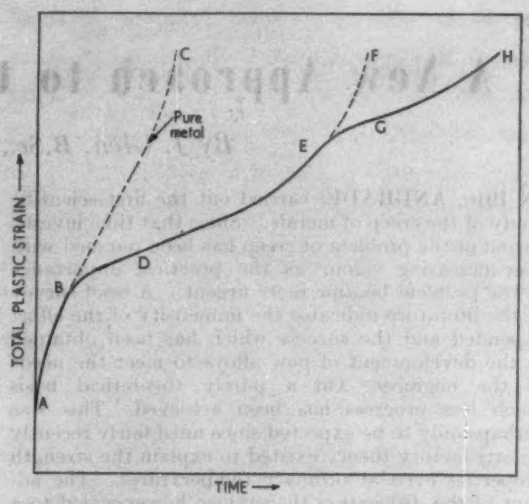

Fig. 2—Diagrammatic creep curve showing transitions

what will be called a transition in creep rate. In Fig. 2 a transition in creep rate occurs over the interval BD so that the complete shape of the curve with one ageing effect is ABDEF. Such transitions can occur at any stage in a creep test and in most commercial alloys more than one transition is obtained. The effect of a second transition in creep rate is also illustrated in Fig. 2. In this case, the transition occurs over the interval EG, during the third stage of creep, so that the complete curve has the shape ABDEGH.

The above phenomenon is easily detected when it occurs during the third stage of creep and examples

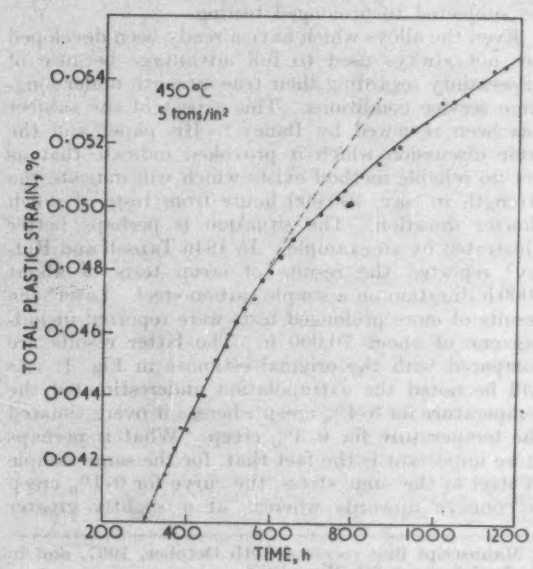

Fig. 3—Part creep curve on 1% Mn steel

Table I
DETAILS OF THE STEELS CONSIDERED

Steel	Form	Treatment	Al, lb/ton	C, %	Si, %	S, %	P, %	Mn, %	Mo, %
1	3-in. plate	N. 920° C T. 2 h 650° C	0	0·135	0·14	0·036	0·020	1·20	...
2	1-in. dia.	N. 920° C	1	0·12	0·06	0·039	0·015	0·52	...
3	1-in. dia.	N. 920° C	2½	0·11	0·05	0·027	0·012	0·45	...
4	1-in. plate	N. 920° C	0	0·13	0·04	0·018	0·026	1·00	...
5	1-in. plate	N. 920° C	2	0·13	0·15	0·028	0·025	1·02	...
Ref. 6	Steampipe	Norm.	½	0·09	0·22	0·034	0·023	0·52	0·50
6	1-in. dia.	N. 950° C	½	0·09	0·22	0·032	0·018	0·48	0·50

have often been reported in the literature.[6, 11] When a transition occurs at an earlier stage it is not usually obvious using normal methods of plotting. A good example is, however, shown in Fig. 3 which illustrates part of a creep curve on a 1·0% Mn steel at a stress of 5 tons/in² and a temperature of 450° C. In this case a transition begins after about 550 h of testing.

When plotting creep data, particularly with extrapolation in view, it is usual to use the logarithm of the time to reach a given strain as one axis. Transitions in creep rate, however, occur at different strains and at different times depending on the stress and temperature of testing. Thus, the shape of the curves obtained by plotting the times for given strains as in Fig. 1 gives no real indication of the trend of the curves when extrapolated to longer times. For this reason a new method of plotting is necessary which will show the transitions in creep rate in their true perspective. To do this, it was decided to use creep rate since this is a measure of the 'instantaneous strength' at any point on a creep curve. Creep rate, however, must be combined with strain so that, in any attempt to extrapolate, the time can be evaluated by integration.

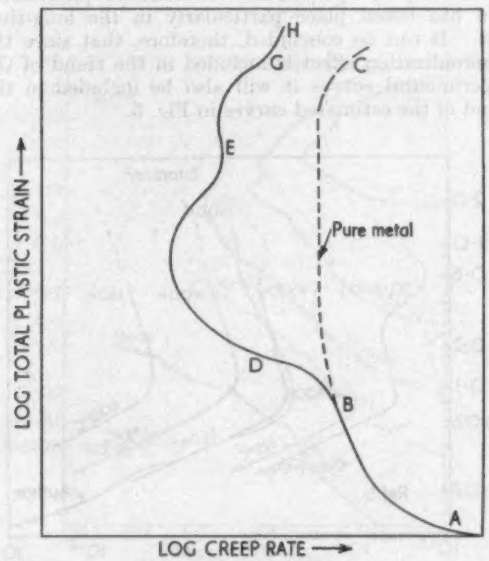

Fig. 4—Diagrammatic strain/rate curve showing two transitions

The two axes of the required method of plotting are thus the total plastic strain and the creep rate. It was found more convenient, however, to use log strain and log creep rate. The latter at least appears to have some theoretical justification as being a measure of the activation energy for creep. When plotted in this way the creep curves shown in Fig. 2 now have the appearance shown in Fig. 4. For simplicity such curves will be called *strain/rate curves*. As might have been expected the simple creep curve ABC typical of a pure metal gives a simple strain/rate curve (ABC). The creep rate slows down until at a certain strain it becomes constant. At a later stage the creep rate increases. The other strain/rate curve in Fig. 4 refers to the creep curve with two transitions in creep rate which are clearly depicted. Indeed, when creep curves are plotted in this way, transitions can be detected which are not obvious from a visual inspection of the ordinary strain/time creep curve.

Many different shapes of strain/rate curves are obtained depending on the material, its heat-treatment, and the stress and temperature of testing. As already mentioned, a detailed consideration of the problem will be deferred to a later paper. At this stage, however, it can be stated that with increasing initial creep resistance the strain/rate curve is displaced to lower creep rates. The greater the latent creep resistance the more pronounced or more numerous will be the transitions in creep rate obtained, although in some cases quite a high deformation may result before the latent creep resistance becomes effective. It is difficult to estimate the effect of spheroidization on the strain/rate curves. Obviously, however, as spheroidization occurs the creep rate at any point will be greater than in the absence of spheroidization. Thus the strain/rate curves must include this effect even although it cannot be separated from the effect of the other phenomena.

Before dealing with some of the practical applications of strain/rate curves, mention should be made

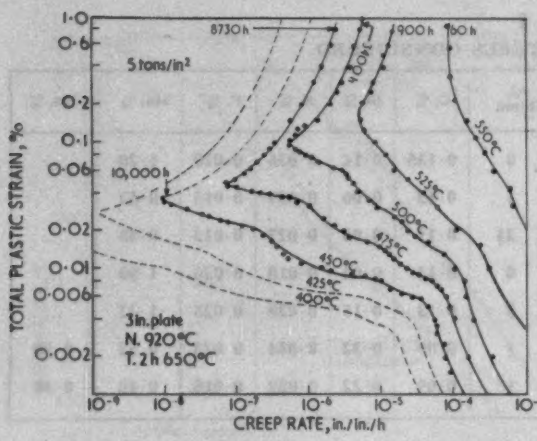

Fig. 5—Family of strain/rate curves at constant stress on 1·2% Mn steel 1

of the method of obtaining such curves. In the first instance it is necessary to plot the strain and time readings using a scale much larger than is commonly used. A smooth curve is then drawn through the plotted points. From the smooth curve so obtained the creep rate is measured at small intervals of strain and from these values the strain/rate curve can be plotted. A detailed description of the method is given in the appendix to this paper.

FAMILIES OF STRAIN/RATE CURVES

When investigating the creep or rupture properties of any particular material it is usual to carry out a series of tests either at constant stress and various temperatures or at constant temperature and various stresses. It is of interest therefore to examine the pattern of strain/rate curves obtained from such a series of tests. In the present paper, attention is confined mainly to tests carried out on a few carbon–manganese steels, but the results of a series of tests on 0·5% Mo steel carried out by Ridley[6] are also included. Details of the steels considered, all of which were made by the basic open-hearth process, are given in Table I.

The 1·2% Mn steel in the normalized and tempered condition was tested using a stress of 5 tons/in² at several temperatures. The strain/rate curves obtained are shown in Fig. 5. Ignoring for the moment the pecked curves, it will be seen that each of the test curves shows three transitions in creep rate and that these transitions occur at lower strains the lower the temperature of testing. It will also be noted that the third stage of creep begins more abruptly and at lower strain values the lower the temperature of testing. At temperatures above about 500° C, the regularity of the pattern changes because at these high temperatures recovery and recrystallization effects occur which are absent in the tests at lower temperature. Thus from the regularity of the pattern at the lower temperatures it is possible to estimate the strain/rate curves for still lower temperatures. Such curves are shown by pecked lines. Because of the chance of experimental error these curves were drawn by making a slight underestimate of their probable position. From these curves the long-time properties can be calculated as is discussed later.

The interesting feature of the curves in Fig. 5 relates to the fact that the latent creep resistance is shown up in its true perspective so that many of the difficulties associated with the interpretation of creep tests are eliminated. There remains the difficulty, however, that the effect of spheroidization is still unknown so that the estimated curves might be in error. The justification of the above procedure is as follows. Spheroidization must operate at all temperatures. But the creep rate is a measure of the 'instantaneous strength' at any point on the creep curves. Thus, the strain/rate curves obtained experimentally include the effect of spheroidization as well as the effect of the initial and latent creep resistance. It might be expected, therefore, that the estimated strain/rate curves for lower temperatures will also include the effect of spheroidization since they are based on the trend of the experimental curves. To prove this conclusively would require very long-time creep tests and fortunately the 70,000-h creep tests by Ridley[6] on carbon and 0·5% Mo steels provide the necessary evidence. Only the latter need be considered.

From Ridley's published creep curves it was possible to calculate creep rates and draw strain/rate curves (Fig. 6), although, of course, the fine detail is missing. The author has, however, included the results of a test on a very similar material (steel 6) which shows that four transitions in creep rate are obtained with this type of steel. The fourth transition in creep rate is clearly shown on the curves, particularly on those for the lower temperatures. The important point about these curves, however, is that they show a uniform trend even although the work of Bailey[12] proves that considerable spheroidization has taken place particularly in the long-time test. It can be concluded, therefore, that since the spheroidization effect is included in the trend of the experimental curves it will also be included in the trend of the estimated curves in Fig. 5.

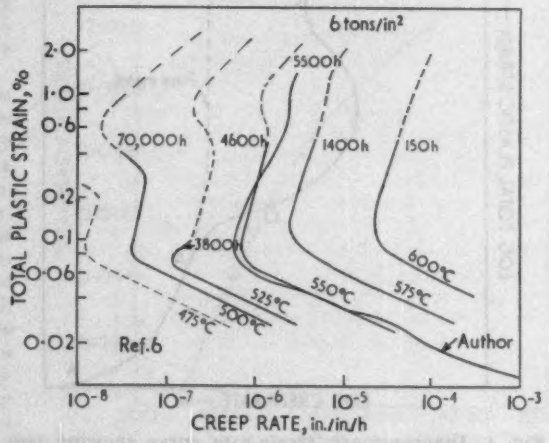

Fig. 6—Family of strain/rate curves on 0·5% Mo steel

Tests to rupture at a temperature of 450° C and various stresses were carried out on steels 2–5. The strain/rate curves on the two 1% Mn steels are shown in Figs. 7 and 8. It will be noted that the aluminium-killed steel shows only two transitions in creep rate whereas the other steel shows three. The aluminium-killed steel thus has a lower latent creep resistance and is inferior in strength particularly at low testing stresses.

When testing at constant stress (Figs. 5 and 6) the initial plastic extension does not vary appreciably so that at the beginning of the tests the strain/rate curves are approximately parallel. In the tests at constant temperature (Figs. 7 and 8), however, the initial plastic extension varies enormously being zero at 5 tons/in² and increasing to nearly 2% at 14 tons/in². For this reason it is more difficult in this case to estimate the trend of the strain/rate curves. A tentative extrapolation has, however, been made as is shown by the hatched lines. It is believed that these curves represent a conservative estimate of the properties of these steels. Obviously, however, much longer time tests would be necessary before a precise estimate of the complete shape of these curves could be made.

EXTRAPOLATION

At the moment there is a trend, particularly on the Continent, to carry out rupture tests for the full service life (10 years) in order to establish accurate working stresses for established materials. While such a method is possible using multi-unit rupture testing machines, it would be extremely costly when using high-sensitivity creep units holding one test-piece. In any case, the above method implies a wait of about 15 years before a new material can be used to full advantage. Even so, after all this work it might be found that the new material was not a great improvement on existing alloys. It is thus of vital importance to be able to estimate the long-time properties of any particular material from tests of much shorter duration.

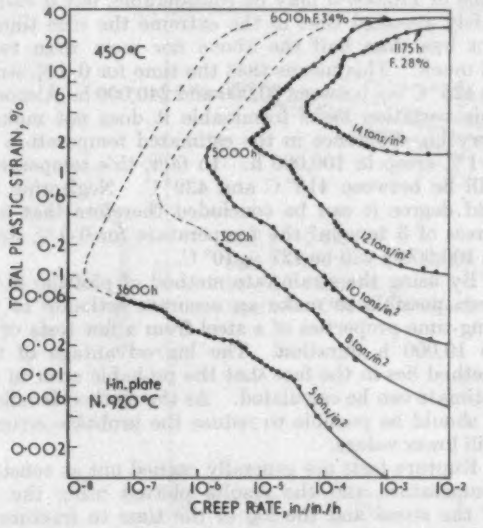

Fig. 7—Family of strain/rate curves at constant temperature on 1% Mn steel 4

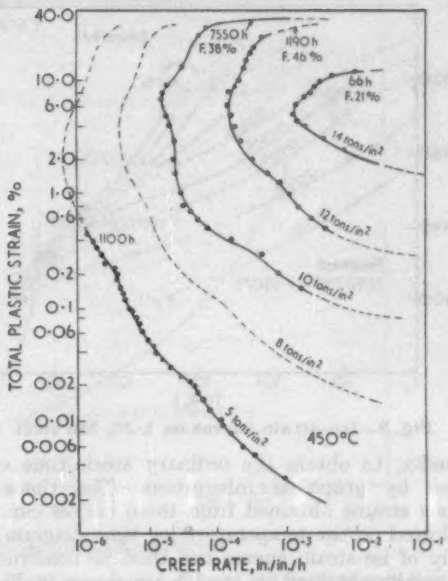

Fig. 8—Family of strain/rate curves at constant temperature on Al-killed 1% Mn steel 5

The difficulties and uncertainties of the most commonly used methods of extrapolation have been reviewed by Bailey[4] and it would appear that as yet no method has been devised which can be considered satisfactory. For the present purpose, use will be made of the method of plotting of one well-known method of extrapolation which uses the results of a series of constant-stress creep tests at different testing temperatures. From the creep curves the times to reach various strains are measured and the results plotted using temperature and log time as ordinates. By drawing smooth curves through these points a family of iso-strain curves can be constructed. It is then usual to extrapolate these curves to longer times but, as was discussed in relation to Fig. 1, the shape of an iso-strain curve up to any given time is not necessarily a guarantee that the same trend will continue in longer times. By making use of strain/rate curves, however, this difficulty can be overcome in the following manner.

If the creep test results are used to construct a family of strain/rate curves it is then possible, at least approximately, to deduce the shape and position of the strain/rate curves of tests at lower temperature. One such series of strain/rate curves is shown in Fig. 5 which represents tests on the 1·2% Mn steel 1 in the normalized and tempered condition. Leaving aside for the moment any question of accuracy, from the actual experimental data the times for various strains up to 1% can be measured and plotted on a temperature/log time diagram. From the estimated strain/rate curves it is an easy matter, as shown in the

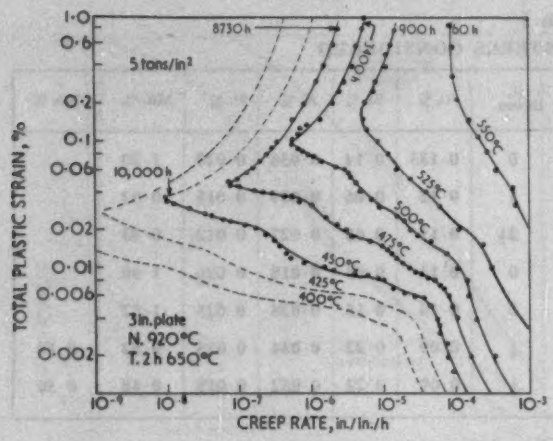

Fig. 5—Family of strain/rate curves at constant stress on 1·2% Mn steel 1

of the method of obtaining such curves. In the first instance it is necessary to plot the strain and time readings using a scale much larger than is commonly used. A smooth curve is then drawn through the plotted points. From the smooth curve so obtained the creep rate is measured at small intervals of strain and from these values the strain/rate curve can be plotted. A detailed description of the method is given in the appendix to this paper.

FAMILIES OF STRAIN/RATE CURVES

When investigating the creep or rupture properties of any particular material it is usual to carry out a series of tests either at constant stress and various temperatures or at constant temperature and various stresses. It is of interest therefore to examine the pattern of strain/rate curves obtained from such a series of tests. In the present paper, attention is confined mainly to tests carried out on a few carbon–manganese steels, but the results of a series of tests on 0·5% Mo steel carried out by Ridley[6] are also included. Details of the steels considered, all of which were made by the basic open-hearth process, are given in Table I.

The 1·2% Mn steel in the normalized and tempered condition was tested using a stress of 5 tons/in² at several temperatures. The strain/rate curves obtained are shown in Fig. 5. Ignoring for the moment the pecked curves, it will be seen that each of the test curves shows three transitions in creep rate and that these transitions occur at lower strains the lower the temperature of testing. It will also be noted that the third stage of creep begins more abruptly and at lower strain values the lower the temperature of testing. At temperatures above about 500° C, the regularity of the pattern changes because at these high temperatures recovery and recrystallization effects occur which are absent in the tests at lower temperature. Thus from the regularity of the pattern at the lower temperatures it is possible to estimate the strain/rate curves for still lower temperatures. Such curves are shown by pecked lines. Because of the chance of experimental error these curves were drawn by making a slight underestimate of their probable position. From these curves the long-time properties can be calculated as is discussed later.

The interesting feature of the curves in Fig. 5 relates to the fact that the latent creep resistance is shown up in its true perspective so that many of the difficulties associated with the interpretation of creep tests are eliminated. There remains the difficulty, however, that the effect of spheroidization is still unknown so that the estimated curves might be in error. The justification of the above procedure is as follows. Spheroidization must operate at all temperatures. But the creep rate is a measure of the 'instantaneous strength' at any point on the creep curves. Thus, the strain/rate curves obtained experimentally include the effect of spheroidization as well as the effect of the initial and latent creep resistance. It might be expected, therefore, that the estimated strain/rate curves for lower temperatures will also include the effect of spheroidization since they are based on the trend of the experimental curves. To prove this conclusively would require very long-time creep tests and fortunately the 70,000-h creep tests by Ridley[6] on carbon and 0·5% Mo steels provide the necessary evidence. Only the latter need be considered.

From Ridley's published creep curves it was possible to calculate creep rates and draw strain/rate curves (Fig. 6), although, of course, the fine detail is missing. The author has, however, included the results of a test on a very similar material (steel 6) which shows that four transitions in creep rate are obtained with this type of steel. The fourth transition in creep rate is clearly shown on the curves, particularly on those for the lower temperatures. The important point about these curves, however, is that they show a uniform trend even although the work of Bailey[12] proves that considerable spheroidization has taken place particularly in the long-time test. It can be concluded, therefore, that since the spheroidization effect is included in the trend of the experimental curves it will also be included in the trend of the estimated curves in Fig. 5.

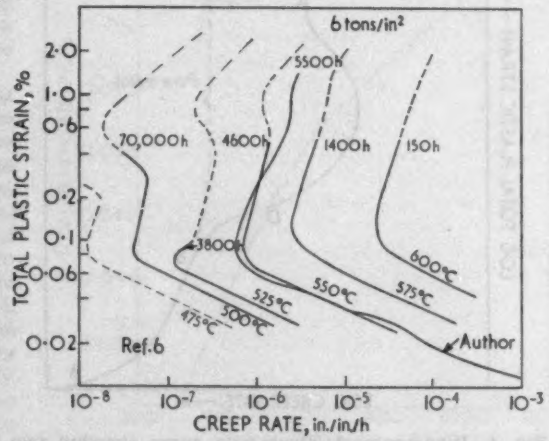

Fig. 6—Family of strain/rate curves on 0·5% Mo steel

Tests to rupture at a temperature of 450° C and various stresses were carried out on steels 2–5. The strain/rate curves on the two 1% Mn steels are shown in Figs. 7 and 8. It will be noted that the aluminium-killed steel shows only two transitions in creep rate whereas the other steel shows three. The aluminium-killed steel thus has a lower latent creep resistance and is inferior in strength particularly at low testing stresses.

When testing at constant stress (Figs. 5 and 6) the initial plastic extension does not vary appreciably so that at the beginning of the tests the strain/rate curves are approximately parallel. In the tests at constant temperature (Figs. 7 and 8), however, the initial plastic extension varies enormously being zero at 5 tons/in² and increasing to nearly 2% at 14 tons/in². For this reason it is more difficult in this case to estimate the trend of the strain/rate curves. A tentative extrapolation has, however, been made as is shown by the hatched lines. It is believed that these curves represent a conservative estimate of the properties of these steels. Obviously, however, much longer time tests would be necessary before a precise estimate of the complete shape of these curves could be made.

EXTRAPOLATION

At the moment there is a trend, particularly on the Continent, to carry out rupture tests for the full service life (10 years) in order to establish accurate working stresses for established materials. While such a method is possible using multi-unit rupture testing machines, it would be extremely costly when using high-sensitivity creep units holding one test-piece. In any case, the above method implies a wait of about 15 years before a new material can be used to full advantage. Even so, after all this work it might be found that the new material was not a great improvement on existing alloys. It is thus of vital importance to be able to estimate the long-time properties of any particular material from tests of much shorter duration.

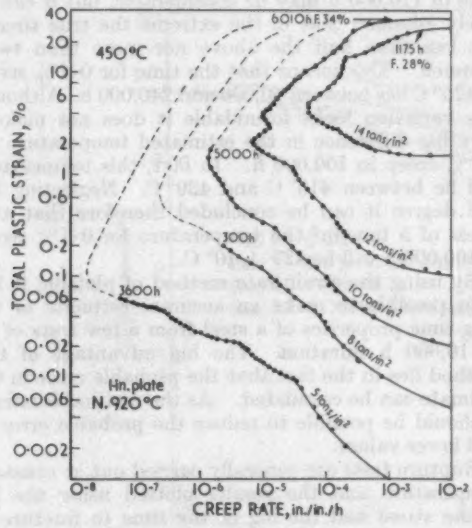

Fig. 7—Family of strain/rate curves at constant temperature on 1% Mn steel 4

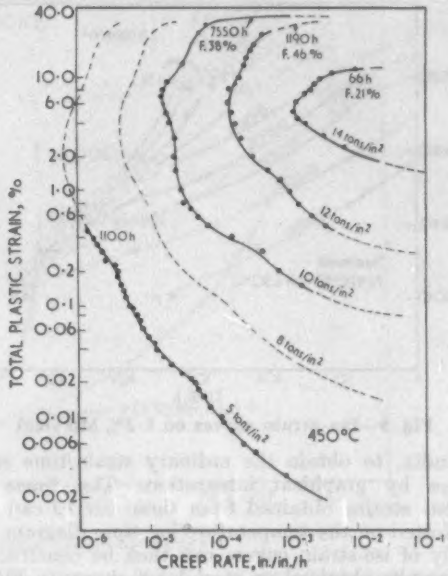

Fig. 8—Family of strain/rate curves at constant temperature on Al-killed 1% Mn steel 5

The difficulties and uncertainties of the most commonly used methods of extrapolation have been reviewed by Bailey[4] and it would appear that as yet no method has been devised which can be considered satisfactory. For the present purpose, use will be made of the method of plotting of one well-known method of extrapolation which uses the results of a series of constant-stress creep tests at different testing temperatures. From the creep curves the times to reach various strains are measured and the results plotted using temperature and log time as ordinates. By drawing smooth curves through these points a family of iso-strain curves can be constructed. It is then usual to extrapolate these curves to longer times but, as was discussed in relation to Fig. 1, the shape of an iso-strain curve up to any given time is not necessarily a guarantee that the same trend will continue in longer times. By making use of strain/rate curves, however, this difficulty can be overcome in the following manner.

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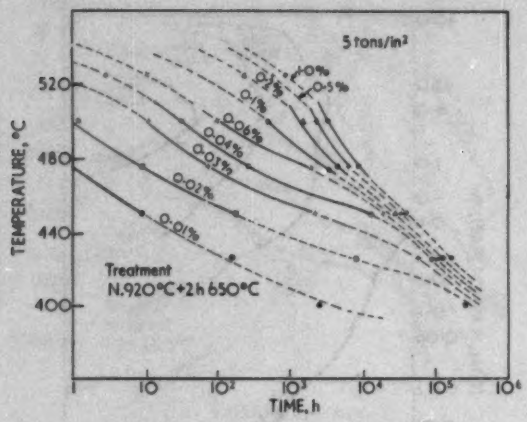

Fig. 9—Iso-strain curves on 1·2% Mn steel

appendix, to obtain the ordinary strain/time creep curves by graphical integration. The times for various strains obtained from these curves can also be plotted on the temperature/log time diagram. A family of iso-strain curves can then be constructed. The results obtained on steel 1 are shown in Fig. 9. The full curves cover the region of accurate experimental data. Pecked curves have been used at the top of the diagram because as the temperature is increased in this region the time for any given strain decreases rapidly in a manner which is not related to the shape of the curves at lower temperature. This can result from the tempering effect of holding the test-piece for some time at the test temperature before loading. It can also occur because of rapid recovery above a certain test temperature or because of a rapid increase in the initial plastic extension with increasing temperature. It may even occur due to scaling or decarburization of the test-pieces at high temperature. The top part of the diagram can thus be ignored though it serves to indicate that short-time tests at high temperature are of doubtful accuracy even for comparing materials or as acceptance tests.

The pecked curves in the lower part of Fig. 9 indicate the region of extrapolation. It will be noted that the iso-strain curves show a distinct bulge. This becomes more pronounced and tends to occur at longer times the lower the strain value considered. Since this must relate to the fact that the minimum in creep rate occurs at a lower strain the lower the testing temperature, and since the latter is a consequence of the latent creep resistance, it seems clear that the bulge in the iso-strain curves is also due to the same cause. In cases where the strain/rate curves show more than one minimum in creep rate, more than one bulge will be obtained in the iso-strain curves although they will not necessarily be so pronounced as those shown in Fig. 9. For example the 0·5% Mo steel (Fig. 6) would have shown two minima in creep rate if the tests had been prolonged to higher strains. The iso-strain curve for a given strain should thus show two bulges in different temperature regions.

It can be concluded, therefore, that the iso-strain curves in Fig. 9 are of the correct shape. It is, however, necessary to make some estimate of the accuracy of the extrapolation. A complete review of this aspect of the subject must await more detailed testing. A few remarks can, however, be made. The accuracy of the extrapolation depends on three factors, namely, material variations, testing errors, and errors in the estimated strain/rate curves. Material variations within a cast and from cast to cast can be assessed by a sufficient number of duplicate tests. Testing errors at strains of 0·1% or above should not be great using modern high-sensitivity creep-testing equipment. It is, however, difficult to obtain precise agreement at low strain values, particularly below 0·01%, but this is of little consequence when considering long-time tests. The measurement of creep rate at longer testing times is comparatively easy and should present no difficulty. However, as the creep rate approaches a value of 10^{-6} in./in./hour or less it becomes almost impossible to assess the creep rate, simply because it would require tens of thousands of hours of test to show the trend accurately. Such tests, however, are entering the region where it is necessary to estimate the strain/rate curves from the pattern obtained at higher testing temperatures.

As explained previously, the estimated strain/rate curves were drawn simply from an examination of the pattern of the known strain/rate curves and using what was considered to be a slight underestimate of their probable position. This seems to be a justifiable procedure since the very long-time tests in Fig. 6 seem to show a regular pattern even at low testing temperatures. It is to be hoped, however, that as more information is obtained over a variety of test conditions and with various materials, it will be possible to define more clearly the laws governing the trend of the curves.

In Fig. 9 the estimated time to reach 0·1% strain at a temperature of 425° C is 116,000 h and from the graph the temperature to give 0·1% strain in 100,000 h is 427° C. It is known that the error in the estimated time of 116,000 h may be considerable, but it can be safely assumed that in the extreme the true time is not less than half the above nor more than twice as much. This means that the time for 0·1% strain at 425° C lies between 60,000 and 240,000 h. Although this variation looks formidable it does not make a very big difference in the estimated temperature for 0·1% creep in 100,000 h. In fact, this temperature will lie between 418° C and 439° C. Neglecting the odd degree it can be concluded therefore that at a stress of 5 tons/in² the temperature for 0·1% strain in 100,000 h will be 427 $\pm$ 10° C.

By using the strain/rate method of plotting it has been possible to make an accurate estimate of the long-time properties of a steel from a few tests of up to 10,000 h duration. The big advantage of this method lies in the fact that the probable error in the estimate can be calculated. As the method is refined it should be possible to reduce the probable error to still lower values.

Rupture tests are generally carried out at constant temperature and the results plotted using the log of the stress and the log of the time to fracture as ordinates. Since, with this method of plotting, the test results often lie approximately on a straight line

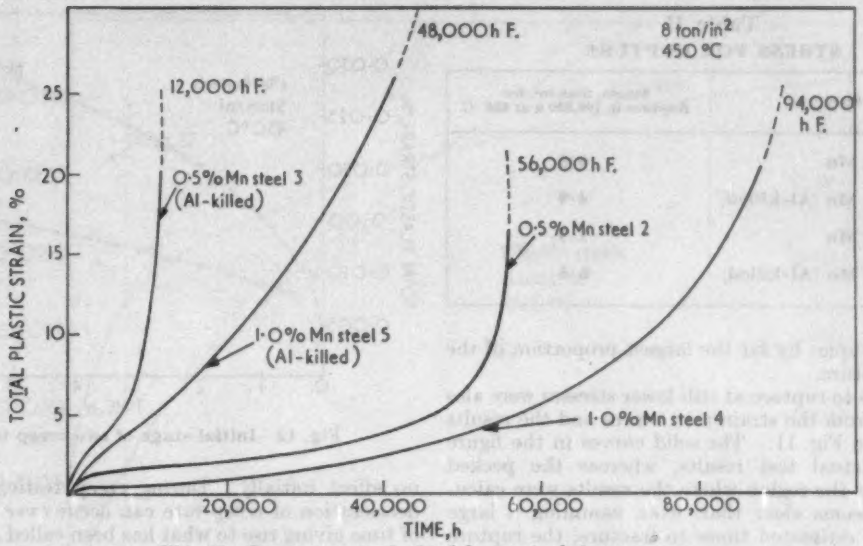

Fig. 10—Creep curves derived from strain/rate curves

it has been assumed that this straight-line relationship holds for still longer times. In this way an estimate of the rupture strength in 100,000 h at the test temperature can be obtained. Even if such a relationship could be proved to hold for one material it is not necessarily correct for other materials or even for the same material at a different test temperature.

The results on steels 2–5 will be used to illustrate the possibilities of the new method although it is more difficult in this case to estimate the probable accuracy of the extrapolation. The accuracy would be improved, however, by longer-time tests. It would be helpful also if the position of the estimated strain/rate curves was cross-checked by carrying out tests at constant stress. Such tests are in hand and an improved design of extensometer is being used for these high strains.

It can be assumed, however, that the estimated strain/rate curves at 8 tons/in² (Figs. 7 and 8) are reasonably accurate since they are only one step away from the known curves. The creep curves to fracture were calculated by graphical integration, with the results shown in Fig. 10. Although the elongation at fracture is not known, this factor does not greatly influence the estimated time to fracture for steels 2, 3, and 4. With steel 5 an error is introduced which is probably not large since the elongation of this steel should be high. An interesting feature of these results is the fact that, except for steel 2, the beginning of third-stage creep does not denote the imminence of failure. The third stage

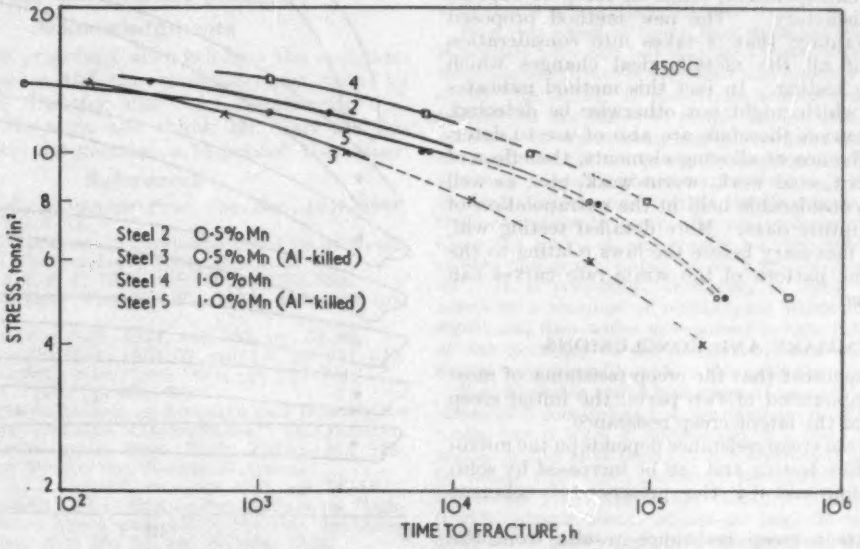

Fig. 11—Rupture tests calculated from strain/rate curves

Table II
STRESS FOR RUPTURE

	Steel	Stress, tons/in², for Rupture in 100,000 h at 450° C
2	0·5% Mn	6·8
3	0·5% Mn (Al-killed)	4·9
4	1·0% Mn	7·9
5	1·0% Mn (Al-killed)	6·5

of creep occupies by far the largest proportion of the time to rupture.

The times to rupture at still lower stresses were also calculated from the strain/rate curves and the results are shown in Fig. 11. The solid curves in the figure represent actual test results, whereas the pecked curves cover the region where the results were calculated. It seems clear that, even assuming a large error in the estimated times to fracture, the rupture curves bend downwards with increasing testing times. Thus, straight-line extrapolation of rupture data can seriously overestimate the properties of a material.

The stress to cause rupture in 100,000 h at 450° C taken from Fig. 11 is given in Table II. The accuracy of the results is probably of the order of $\pm$ 0·5 tons/in². As was the case for the creep tests this permits a substantial variation in the estimated times to fracture.

In some materials, intercrystalline failure may occur in long-time rupture tests resulting in a low elongation at fracture. For this reason the terminal point of the estimated strain/rate curves must also be known before an accurate estimate of the rupture time can be obtained. This aspect of the subject is quite complex and will be dealt with in a separate paper.

As has already been emphasized none of the present methods of extrapolation, either of creep or rupture data, is satisfactory. The new method proposed has the advantage that it takes into consideration the effect of all the metallurgical changes which occur during testing. In fact this method indicates phenomena which might not otherwise be detected. Strain/rate curves therefore are also of use to determine the influence of alloying elements, the effect of heat-treatment, cold work, warm work, etc., as well as being of considerable help in the extrapolation of creep and rupture data. More detailed testing will, however, be necessary before the laws relating to the shape and the pattern of the strain/rate curves can be formulated.

SUMMARY AND CONCLUSIONS

(1) It is suggested that the creep resistance of most alloys is compounded of two parts: the initial creep resistance and the latent creep resistance.

(2) The initial creep resistance depends on the microstructure before testing and can be increased by solution hardening and by the presence of coherent precipitates.

(3) The latent creep resistance results from the effect of various strain-ageing phenomena and has no effect initially. During creep testing a sudden deceleration of creep rate can occur over an interval of time giving rise to what has been called a transition in creep rate. More than one transition in creep rate occurs in the creep curves of most commercial alloys.

(4) A third effect must also be considered, namely, the overageing or spheroidization of the precipitates, since this tends to reduce the creep resistance.

(5) By plotting the results of creep tests in the form of log strain/log creep-rate curves (strain/rate curves) the effect of the latent creep resistance is clearly depicted.

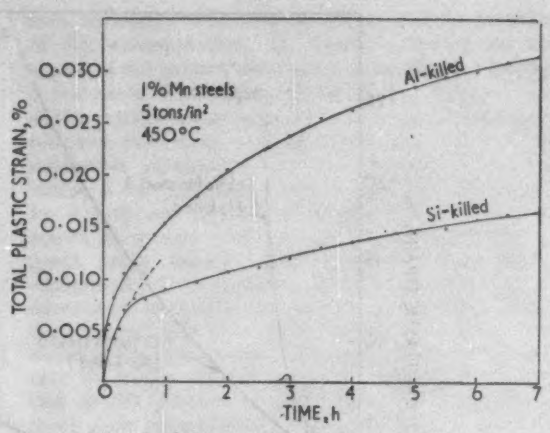

Fig. 12—Initial stage of two creep tests

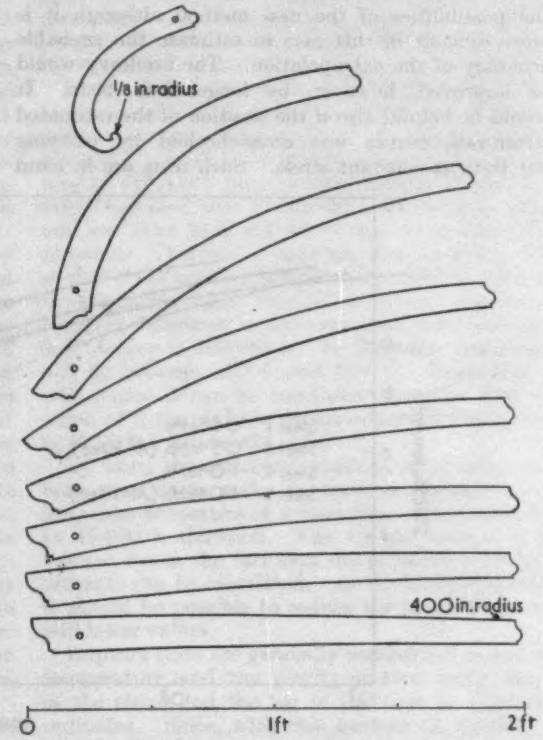

Fig. 13—Weir's graduated curves

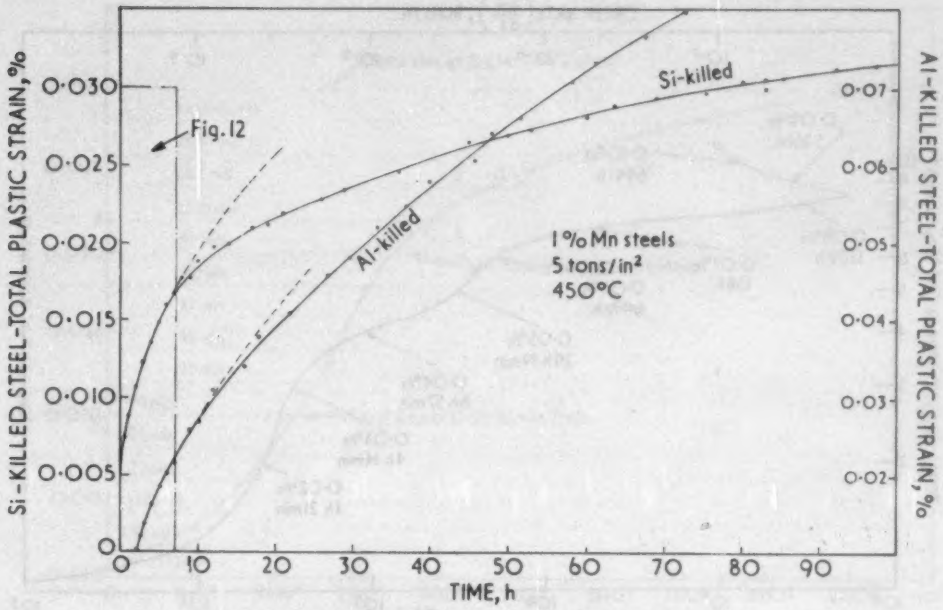

Fig. 14—Intermediate stage of two creep tests

(6) From the pattern of strain/rate curves obtained from a series of creep tests either at constant stress or at constant temperature, it is possible to estimate the strain/rate curves of tests at lower temperatures or stresses. By integrating such curves the ordinary strain/time creep curves are obtained. In this way the results of creep tests or rupture tests can be extrapolated by a method which has some theoretical justification since it takes into consideration all the metallurgical changes which occur during testing.

(7) The results of creep and rupture tests on several steels of 0·5% and 1·0% Mn content were used to demonstrate the extrapolation procedure.

Acknowledgments

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APPENDIX

Plotting and Integration of Strain/Rate Curves

Creep Curves and Creep Rate

In the method of approach to the creep problem proposed in the above paper, it is obvious that the shape of the creep curve is important at all stages of testing. It might be helpful, therefore, to outline the method used for drawing creep curves and measuring creep rate since it is quite possible that a better method could be suggested by some other worker in this field. If so, the author would welcome it since the drawing of creep curves is an exacting and time-consuming task, even although it is essentially simple.

In a creep test of fairly long duration the creep rate is initially very fast but may slow down over a long time until the creep rate is very slow and possibly of the order of 10^{-8} in./in./h. If the whole of this creep curve is plotted on one sheet of graph paper, which might be 50 cm × 70 cm or even larger, it will be found that at no point can the creep rate be measured with sufficient accuracy to define the strain/rate curve. For example in the initial stage of testing the time scale is so small that variations in creep rate are undetectable. In all cases the scales chosen should be such that the curve crosses the graph paper at an angle of approximately 45°. It is necessary, therefore, to draw each creep curve in a number of overlapping parts changing the strain and time scales as required to take full advantage of the accuracy of the strain and time readings. An actual example will explain the procedure more clearly.

Fig. 12 shows the initial stage of two creep tests at a stress of 5 tons/in² and a temperature of 450° C. The steels tested were a normalized Si-killed 1%Mn steel and a similar steel deoxidized with aluminium. It will be noted that the time scale is drawn so that 6 cm represents 1 h. The strain values are plotted so that 0·01% plastic strain equals 10 cm. It is extremely difficult to draw this curve freehand or by using the more common types of french curves or railways curves.

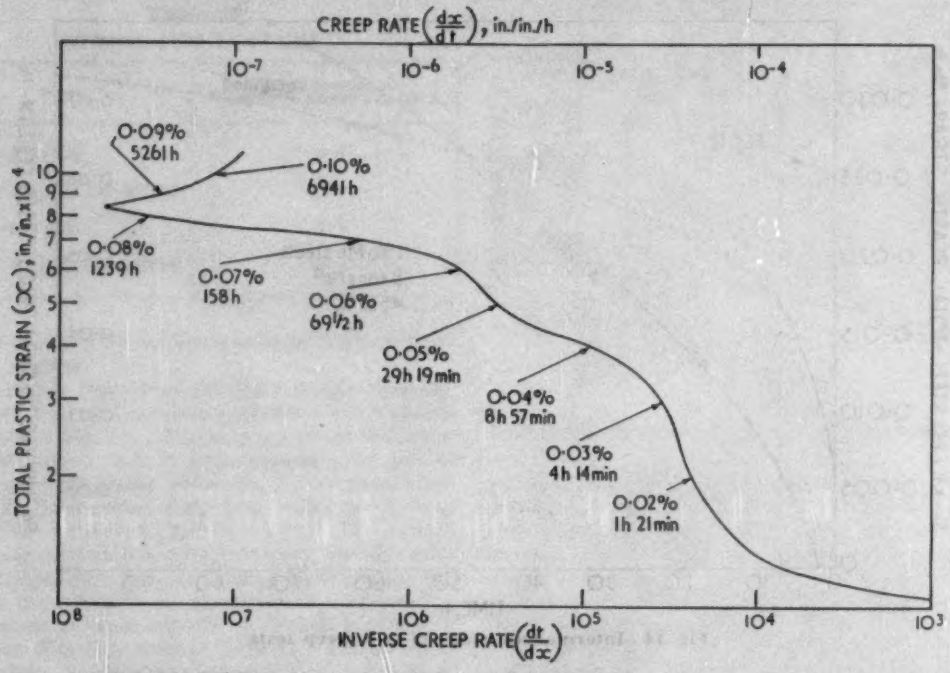


Fig. 15—Strain/rate curve for integration

The author finds it necessary to use a set of Weir's graduated curves. These are shown on a reduced scale in Fig. 13. It will be noted that 6 of the 8 curves are nearly 24 in. long and that the gradient of the set changes gradually from $\frac{1}{8}$ in. radius to about 400 in. radius. The mathematical derivation of these curves appears to have been lost in antiquity.

In Fig. 12 the Al-killed steel does not show a transition in creep rate during the first few hours of test. The other steel, however, shows a marked transition beginning after less than one hour of test. The trend of the first part of the curve is shown by a pecked line. Having obtained the curves shown in Fig. 12 it is easy to measure the creep rates at increasing strain intervals by drawing tangents. More than sufficient creep-rate measurements can be made than are necessary to define the shape of the strain/rate curve. Thus, any slight inaccuracies in the measurement of creep rate are cancelled out.

To draw the next part of the creep curves it is necessary to alter the time scale. As shown in Fig. 14 this scale is drawn so that 5 cm represents 10 h. The strain scale was not altered for the Si-killed steel, but has been halved for the Al-killed steel. The necessity for choosing the correct scale will be appreciated by noting that the marked transition shown in Fig. 12 is quite undetectable in Fig. 14 because of the contraction of the time scale. The contraction of Fig. 12 is indicated on the graph. In Fig. 14, however, a second transition in the curve for the Si-killed steel and the first in the curve for the Al-killed steel become evident particularly when the creep-rate values are plotted on the log strain/log creep-rate basis.

The remainder of the two creep curves is treated in a similar way, contracting or expanding the scales as required by the trend of the curve. The third transition in the creep curve of the 1% Mn steel was shown in Fig. 3. It should be mentioned, however, that in very long testing times, even although the time scale is contracted so that 1000 or 2000 h equals 5 cm, it may be necessary to expand the strain scale to the limit of accuracy of the strain readings.

In such cases the scatter of strain points about the curve is considerable but so many readings are available that the trend of the curve can be drawn quite accurately. In the limit, however, if the creep rate decreases still further it becomes impossible to draw the curve or measure the creep rate with sufficient accuracy since the experimental scatter is greater than the total creep over many thousands of hours.

In the above the experimental variations considered were related to the sensitivity of the extensometer used. In some cases more serious experimental variations are encountered. For example a more or less periodic variation in strain readings can be obtained particularly in long testing times which is possibly due to slight sticking of the extensometer components. Slight variations in temperature may also occur. In very few cases is it possible to confuse the above types of variation with a transition in creep rate. If the results are too erratic, however, the whole test is suspect and should be repeated, or at best given small weight when used as one of a family of strain/rate curves.

Integration of Strain/Rate Curves

As was explained, it is possible from a series of creep tests to draw a family of strain/rate curves from which an estimate of the shape and position of a strain/rate curve for some lower temperature (or stress) can be made. By integrating these estimated curves to obtain the ordinary strain/time creep curves it is thus possible to extrapolate to long testing times such as 100,000 or even 200,000 h. One method of integration is as follows.

Let the strain/rate curve shown in Fig. 15 be one which requires integration. The actual values of time for strains of 0·02%, 0·03%–0·10% are annoted to the curve, these values being obtained by the following procedure.

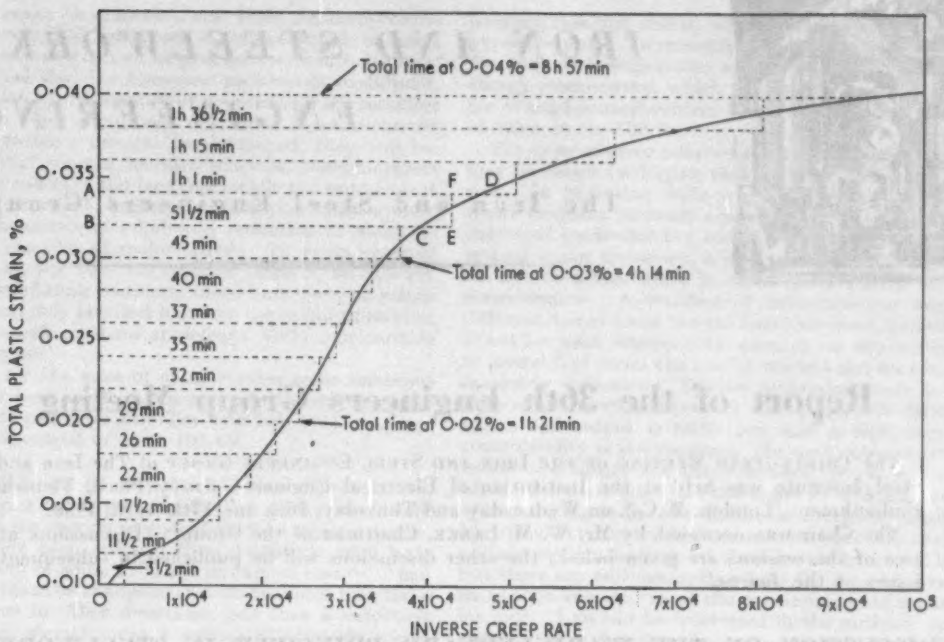


Fig. 16—Inverse creep-rate curve

In Fig. 15 one axis of the plot is the creep rate dx/dt, but for integration of time it is necessary to use the inverse creep rate dt/dx. This is simple to obtain as is shown on the diagram. To integrate, ordinary values of the rate must be used instead of the log values. For this reason each log section of the diagram will be considered separately. The time up to a creep rate of 10^{-4} in./in./h is only a few minutes and can be neglected though it could be calculated if desired. Between creep rates of 10^{-4} and 10^{-5} the log values of the inverse creep rate for a series of plastic strain values are read off and the actual inverse creep-rate values obtained in the usual way from antilog tables. These readings have been plotted in Fig. 16 and a smooth curve drawn through the plotted points. In this example, the graph has been divided into segments the width of each being equal to 0·002% plastic strain, that is 2×10^{-5} in. per in. plastic strain. The mean value of inverse creep rate is taken as the rate during this interval of strain. If greater accuracy is desired the segments can be made narrower. Considering the one segment ABCD marked on the diagram, then

$$\begin{aligned}\text{area ABCD} &= \text{area ABEF} \\ &= 2 \times 10^{-5} \times 4{\cdot}28 \times 10^{5} \text{ hours} \\ &= 0{\cdot}856 \text{ hours} \\ &= 51\tfrac{1}{2} \text{ minutes}\end{aligned}$$

All the other segments are treated in the same way and by summation the time to reach any given strain is obtained. This is also illustrated in the diagram.

By drawing similar graphs the whole strain/rate curve can be covered. A further example where the creep rate is much smaller is shown in Fig. 17. In this case the segment PQRS is typical and

$$\begin{aligned}\text{area PQRS} &= \text{area PQTU} \\ &= 2 \times 10^{-5} \times 4{\cdot}96 \times 10^{7} \text{ hours} \\ &= 992 \text{ hours}\end{aligned}$$

As already mentioned the time to reach various strains have been annoted to the strain/rate curve shown in Fig. 15. Obviously the time for any intermediate strain can be determined. There is no necessity therefore to reproduce the actual creep curve obtained. Strain/rate curves extending to 10% or even 20% plastic strain and where the creep rate may fall to even lower values can be integrated in the same manner although the times obtained may be very large.

Integration of a strain/rate curve can be achieved by various other methods such as by a planimeter and probably also by means of an electronic computer. The above method is, however, quite simple and takes little time even if the total test time is very large.

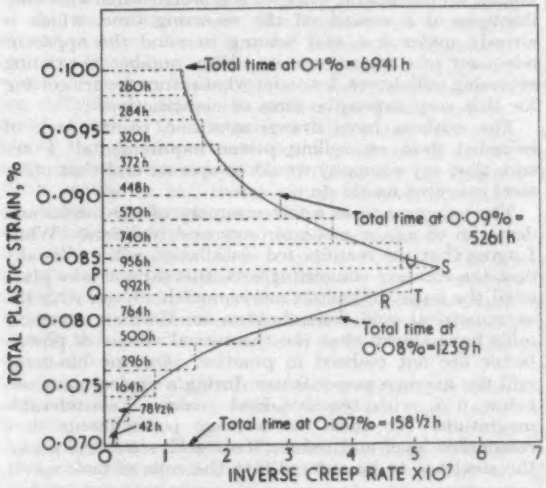
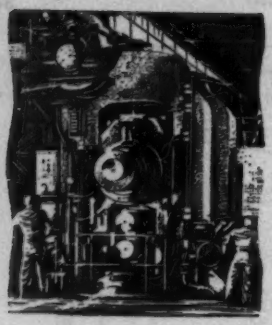


Fig. 17—Inverse creep-rate curve



IRON AND STEELWORKS ENGINEERING

The Iron and Steel Engineers Group

Report of the 36th Engineers Group Meeting

The THIRTY-SIXTH MEETING OF THE IRON AND STEEL ENGINEERS GROUP of The Iron and Steel Institute was held at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2, on Wednesday and Thursday, 16th and 17th April, 1958.

The Chair was occupied by Mr. W. M. LARKE, Chairman of the Group. Discussions at two of the sessions are given below; the other discussions will be published in subsequent issues of the *Journal*.

DISCUSSION ON THE WARD-LEONARD PRINCIPLE IN STEELWORKS

This discussion was based on the paper by G. Ovens and C. A. Dodd, entitled **"Modern Developments of the Ward-Leonard Principle and Applications in Steelworks,"** which appeared in the March, 1958, issue of the *Journal* (vol. 188, pp. 266-276).

Mr. **C. A Dodd** (McLellan and Partners) presented the paper.

Mr. **G. E. Evans** (Steel Company of Wales Ltd.): In examining the requirements for the application of a Ward-Leonard drive one must consider the possibility of the future addition of some form of automatic control. When our 3-stand mill was installed only six or seven years ago, no one talked seriously of automatic gauge control. Today we have such an installation, and if we had had Ward-Leonard screwdown drives the job of making it operate correctly would have been very much easier, and fundamentally more efficient and reliable, satisfactory though the constant-potential contactor control is for its designed duty. On our new 4-stand mill the screwdown will have Ward-Leonard control.

It is possible to be too extravagant in the application of this form of control. For some years we have repeatedly used the Ward-Leonard system on blast-furnace skip hoists, and it was interesting to learn again of the merits of its poor relation, straight contactor control. On the last furnace which we put in we employed a series-parallel arrangement requiring an array of contactors of almost frighteningly large size. After more than two years of operation, however, replacement costs have not been significantly larger than on the other furnaces, which have appreciably smaller contactors. No complaints have been received from the mechanical engineers of lack of smoothness of take-up. Running costs are lower and a saving of several thousand pounds has been shown on overall capital costs. The designed furnace output of 1500 tons/day has been easily maintained and stoppages have been extremely few.

With regard to the application of Ward-Leonard control to auxiliary drives, there was an article by Emms and Morgan* recently on the use of a switched booster in series with the supply of the front and back tables of a reversing primary mill. The object of the booster is to match the speed of the table with the faster outgoing piece following reduction. Has anyone here any experience of such an arrangement, and has it reduced the maintenance on line shaft drives? So heavy has this maintenance become on our mill that we have finally had to resort to individual roller drives on these tables.

On the subject of motor characteristics and the modern trend towards laminated frames for large heavy-current reversing drives, I should like to ask what tangible benefits are obtained from such design. Without provoking arguments on whether it is worth while knocking fractions of a second off the reversing time, which is already under 2 s, and bearing in mind the apparent adequacy of commutation in a large number of existing reversing mill drives, I wonder what return we are getting for this very expensive form of construction.

The authors have drawn attention to the lack of recorded data on rolling power requirements. I am sure that my company would co-operate and that other steel concerns would do the same.

The paper contains a fair summary of the merits and demerits of motor-generator sets and rectifiers. While I agree that the rectifier-fed installation will eventually oust the rotating converting sets, this cannot take place until the basic difficulties are removed. Even with the asymmetrical grid control, tests on German reversing mills have shown that the theoretical values of power-factor are not realized in practice. On one blooming mill the average power-factor during a typical pass was below 0·5, with reactive load peaks of considerable magnitude. To raise the average power-factor to a reasonable level and reduce the reactive current peaks, the steel has to be entered into the rolls at base speed.

* *Elect. Rev.*, 1958, vol. 162, No. 4, pp. 161–167.

This can never be achieved, and even the compromise of an entry at 50% base speed is not acceptable to many mill operators and cannot be practised with all schedules. I do not feel that the harmonic problem is so difficult. The selection of the method of operation of the rectifiers will, I am sure, sort itself out, and, if main-current reversing switches have to be developed, they will be.

In putting forward rectifier schemes, manufacturers should not overlook the fact that, while the initial plant costs may be a little higher, consideration must equally be given to increased reliability, reduction of maintenance, and the cost of major spares. In seven years of operation at our own works of a bank of 30 700-kW pumpless steel-tank rectifiers, there have been no major troubles, and only one unit has been taken out of service, due to a small mechanical defect. Only one tank is held as a spare.

Finally, for the sake of completeness some reference might have been made in the paper to the development of the 50-c/s magnetic amplifier with half-cycle response time and an output of up to 100 kW.

Mr. H. Williams (Metropolitan-Vickers Electrical Co., Ltd.): On p. 272, the authors say "on a recent cold-mill installation the driving motors of the two motor-generating sets were each reduced from 11,500 to 9000 h.p., with a saving of some £100,000 in capital cost." I can appreciate that the change in size of the motor may have repercussions in other directions, but that a reduction of 5000 h.p. should mean a saving of £100,000 seems excessive. The authors also refer to a saving of "at least £3000 a year in running costs," but I cannot see how a change in installed capacity of this order can make such a difference to the running costs.

I support the comments on rectifiers and agree that they will be widely used in the future. Many supply problems exist on large power applications and full co-operation will be required between manufacturers, users, and the supply authority.

I was disappointed that the authors did not deal authoritatively with the assessment of generator sizes for hot reversing mill Ward-Leonard auxiliary drives, e.g. tables, manipulators, screwdowns, etc. On these drives, the motors and generators have to be designed for a certain maximum torque or current and a certain maximum voltage for rapid response; these maxima do not occur at the same instant and hence the maximum kilowatts are not the product of the maximum amps and the maximum volts. The number of operations and r.m.s. rating must also be considered separately from the peak rating. The gear ratio employed by the mechanical makers also plays a major part, and it is often difficult to assess the correct generator size required. Further, the diversity of the r.m.s. and peak loads of the generators on a multi-generator M.G. set greatly influence the size of the M.G. set driving motor.

With regard to Mr. Evans' query concerning half-cycle response magnetic amplifiers, my company has done a considerable amount of work in developing these units. We have built and tested a 100-kW, 160-V unit which has operated satisfactorily on constant current, voltage, and h.p. control, both in armature and field circuits. Performance has been largely in accordance with theory and there appears to be no limit to the size that can be built.

We are now at the stage of considering selective specific applications and are developing a 400-kW unit as a further experiment.

Mr. H. S. Brown (English Electric Co., Ltd.): One of the big advantages of the Ward-Leonard system of control has not been stressed by the authors as much as I feel it warrants. That is the reduction in the energy consumption for drives where a large number of reversals occurs. An example of this is the auxiliary drive for large reversing mills, and it was this reduction in energy consumption which was one of the main reasons for Ward-Leonard control being adopted, for this type of drive, in the U.S.A.

The type of drive adopted for a particular application may be decided solely on this factor of energy consumption. In reversing mills of low and medium power where frequent reversals are not required and where the degree of controllability obtained by the Ward-Leonard system is not necessary, a decision on whether to go to an a.c. or a d.c. drive is often made purely on costs consideration. A number of investigations made at different times have shown that, whereas initially the Ward-Leonard system may seem to be the one to use, in actual fact when the cost is worked out an a.c. drive is clearly indicated. Typical examples occur in non-ferrous mills with drives in the range 500–2000 h.p. where the output is fairly low and a high degree of controlability is not required. In such cases the energy losses in a simple resistance control for the a.c. motor often works out less than the losses of a Ward-Leonard system, owing to the low number of reversals. Rectifiers have tended to tip the scale more in favour of the variable-voltage system because of their lower light-load losses, but there are still examples where the a.c. drive can be more economic and meet the requirements of a particular mill. I should be interested in the authors' experience in the comparison between a.c. drives and Ward-Leonard drives.

Mention is made of the use of a three-field generator for a screwdown drive. With the open-loop system the use of a laminated frame would undoubtedly help in getting a fast response. Was a laminated machine in fact used?

The subject of laminated frames for generators on reversing mill drives has been a subject of debate since the beginning of the century. German reversing-mill drives, made before the first world war, are operating in this country and have laminated frames on the main generators. German equipments manufactured recently still have laminated frames. In the U.S.A. some equipments have laminated frames, some have not. However, there is no doubt that for many drives the use of laminated-frame machines is very definitely an advantage. It helps to get the best controlability and in getting the best out of the machines. It enables the machine to handle rapid transient loads more effectively. The advantages of each case need to be compared with the cost involved, which is not great and in many cases is amply justified.

On rectifiers, I agree with Mr. Williams that the authors have been somewhat optimistic as to the ability of the power supply systems to take the peaks, but they have been somewhat pessimistic about the ability of the electrical industry to provide a rectifier-fed reversing drive. Early tests on the principle of reversing drives fed from rectifiers were done in this country as far back as 1932 and tests on a larger scale were carried out in the early 1940's. Since that time considerable development work has gone on in the U.K. and elsewhere on the design of rectifiers for this type of duty and on the requirements of the control scheme. The electrical industry is now in a position to supply rectifiers for most types of mill drive but there will still be cases where the supply system will not be able to take the peaks associated with a large reversing drive, for example.

Mr. Evans is right on the question of asymmetric grid control. Under over-load conditions the advantage of this form of control is considerably decreased and in most cases it is unlikely that the extra complication

will justify it. Do the authors have any recent information on the experience and present practice on the continent with this type of control?

Mr. **W. N. Jenkins** (B.I.S.R.A.): The problem of control in a multi-stand cold mill, and particularly a tinplate mill, is a very interesting one. Steady progress is being made towards a better understanding of the interaction between separately driven stands linked by strip. Much valuable information is being gathered from the smallest tandem mill in the world, installed at the B.I.S.R.A. laboratories in Sheffield. This mill, which rolls strip ½ in. wide and 0·010 in. thick at 10 ft/min, is a correctly scaled-down version of a full-size mill. The motors are accurately speed-controlled with a tacho-generator and with controlled added droop, and the results testify to the importance of motor-speed regulation in determining the way in which the mill responds to the operator's control. So important is the amount of droop that one would think that accurate speed control with controlled added droop would be desirable in full-size mills rather than voltage control, with which the non-linearity of the motor characteristics remains. Several mills now operate satisfactorily with closed-loop control, and it is surprising that this is not mentioned in the paper.

In the list of drawbacks of rectifiers two are concerned with complication. Expense, lack of reliability, and difficulty of maintenance are disadvantages, but not complication in itself. We might consider a d.c. generator to be complicated, with its multiplicity of brushes and commutator segments and the complex interplay of fluxes, but all is contained within a smooth exterior and the whole is very reliable. Grid control complicates rectifiers, but the complication is all at low power level and intrinsically fairly cheap. With modern magnetic-core techniques reliability is of a high order, and the technique of using plug-in units makes maintenance easy. Up to the present, only analogue methods of control have been used in grid-controlled rectifiers. The firing point of each anode in each cycle is moved forward or backward in time according to the voltage required. This, however, is not the only method possible. One can choose to fire or not to fire each anode during each cycle, and this freedom has never been fully exploited. Much can be done by digital control in improving the power factor at low speed and in avoiding the feed-back of large sustained harmonics from the supply system. A preliminary investigation is under way at B.I.S.R.A. on this subject.

Mr. **K. K. Schwarz** (Laurence, Scott & Electromotors Ltd.): On the continent the development of rectifier drives has gone through all the standard stages and the present tendency seems to be to have individual reversible rectifiers, i.e. cross-connected systems, or to use a fixed-voltage bulk rectifier which overcomes, incidentally, most of the difficulties with harmonics and so on, and to use a rotating machine in buck-boost connection to obtain speed control if required over a wide range. There is, of course, no intrinsic difficulty, as distinct from expense and complication, in reversing the machine because a grid-controlled rectifier can be made to invert. The main difficulty seems to arise if a small and/or fast speed change downwards is required.

For steel mills, as with most processes, reliability is essential and the figures which have been quoted for the reliability of rotating machine sets with outages of 1 hour per 1000 to 2000 hours seem to need considerable emulation compared with the figures currently quoted for rectifier drives.

I agree with Mr. Evans that the limitation of size of self-saturating magnetic amplifiers to 2 kW is conservative; for control purposes 20 kW seems a more realistic and entirely practicable figure. The fact that the magnetic amplifier has an intrinsic minimum time constant of about one half-cycle of supply frequency means that for a power frequency amplifier the response time is 10–20 ms. It is not clear, therefore, why this should be considered a disadvantage in the light of the following control stage with time constants of the order of tenths of seconds for exciters, etc., followed by a main machine time constant of the order of seconds. I should like to ask the authors why 400 c/s was chosen in the case mentioned in the paper as this seems too low a frequency for optimum design whilst still requiring a special supply.

Semi-conductor devices behave in principle in the same way as electronic discharge devices. The application of silicon devices mentioned in the paper has already become quite general whereas the use of germanium devices for small units, where conditions cannot be carefully controlled, seems to be of doubtful advantage from the point of view of reliability. I should like to know what experience, if any, is available with germanium and silicon devices. There is no doubt that, as silicon devices become more economically available, considerable extension of their range of application, both for diodes and transistors, will occur.

Mr. **S. A. G. Emms** (General Electric Co., Ltd.): With controls and by the use of magnetic and electronic amplifiers it is possible to do almost anything with the Ward-Leonard drive in the way of speed and accuracy, and the question arises of where to draw the line. Capital cost and complexity tend to rise rather rapidly if it is desired to get the last ounce out of these things; and, if they are very complex, they set the unfortunate maintenance man a super crossword puzzle which has to be solved against time.

Now that we have this speed and accuracy established, I think that we are beginning to need new sensing devices for the measurement of speed, position, and so on to go with them, and I think that they are becoming available to match the new power-control techniques. I agree with the authors that we are likely to see more and more rectifier applications of increasing size. I saw a number of them in the U.S.A., and I think that all we await now is the building up of a sufficient body of experience.

There are one or two features which have to be borne in mind. One of them is the sensitivity of the mercury-arc rectifier, in particular to temperature and to sudden voltage changes on the input side. In this matter it differs, of course, quite profoundly from a motor-generator set, which will iron-out voltage changes without causing excessive load fluctuations. Frequency changes, of course, are less serious because slower.

I should like to know why the authors favour armature-reversing switches and regard the field reverser as difficult, because with laminated fields, which are also becoming more common, it is merely a matter of providing high voltage, which is rather favoured by a rectifier, which works well at high voltages. Field reversal, by eliminating altogether a rather formidable piece of apparatus, i.e. the armature-reversing switch, seems attractive to me.

Finally, I should like to ask the authors how far they think that the performance of these very complicated interlocking systems can be forecast by the use of the analogue computer. We have made a few efforts in that direction which have not been discouraging. One difficulty is to arrive at parameters. It is extremely difficult to extract from a d.c. designer the inductance of a large d.c. armature, without which it is not possible

to get very far. It seems, however, that even if it does not give a nice tight numerical answer it will at any rate show where the shoe pinches, and that should be enough for a designer, because it is then only a matter of allowing for a little development.

Mr. **W. Spence** (British Thomson-Houston Co. Ltd.): When twin motor drives are used, as opposed to single motor drive, the problem of load-sharing and of matching transient performance is particularly acute with separate armature circuits and a rectifier supply. The transient problem emphasizes the need for rapid reversal of power flow, so that variations in timing have as small an effect as possible. The system most likely to give the best results is the one using armature-reversing switches, assuming that the cross-connected rectifier is out for economic reasons. One switch, developed in Germany, has a very satisfactory record of reliability and comparatively low maintenance, and here I disagree rather strongly with Mr. Emms in his description of such a switch as a formidable device. I think that it is a very simple device. The key to sound operation of the method using armature reversal is in the design of the control circuits to ensure that switching takes place only at zero current.

As for the use of variable voltage on continuous hot mills, low regulation, as the authors say, is desirable. In presenting the paper, Mr. Dodd mentioned that a high inertia is a desirable feature of motors with low impact speed drop and allows the regulator time to come into action when load is applied. It is worth adding that fast-acting regulators operating in the armature circuit can nevertheless minimize impact speed drop.

The increasing use of magnetic amplifiers offers steelworks engineers increased reliability and reduced maintenance compared with rotating amplifiers. Nevertheless there are some applications where the control is kept simpler and performance and efficiency are better if rotating amplifiers are used. Incidentally, Fig. 2 of the paper is, in my opinion, an unfortunate example of the application of magnetic amplifiers, because the great advantage of the device, which is its static nature, is offset by the use of two further rotating amplifiers. Why not use the magnetic amplifier to excite the generator?

In conclusion I would say that a very big future remains for variable-voltage control in steelworks, and it is certain that controlled rectifiers will play an increasing part in this field.

Mr. **F. B. Levetus** (Keelavite Rotary Pumps and Motors Ltd.): The authors have shown an efficiency curve for a Ward-Leonard drive under varying conditions of voltage and load, but for a restricted speed range, about 3/1. I should like to know the form of such curves nearer to zero.

Secondly, I should be very interested to know what degree of stiffness of a Ward-Leonard drive, particularly at low speed, can be obtained without closed-loop control.

Thirdly, I should like to have some indication, if it is possible to give it in a general way, of the relationship of stored energy in Ward-Leonard rotors to the power which they are handling.

Mr. **J. C. Christie** (English Electric Co., Ltd.): As has been pointed out, the effectiveness of current limiting, especially on a high-inertia auxiliary drive, is extremely important and one of the advantages of using the magnetic amplifier as a first-stage amplifier is that it is possible to obtain a fast cut-off to the initial rise of current and a good level current characteristic during the acceleration of the motor.

It was mentioned that Ward-Leonard control on cold-mill screwdowns is being used to make the systems adaptable for automatic gauge control. In a hot-mill automatic screwdown this is undoubtedly so, but with cold mills 'on–off' screwdowns are suitable for many applications. What results have been obtained to make 'on–off' control undesirable for automatic gauge control?

An example was shown of the ingot bogie using collector rails with carriage-mounted motors. The tendency now seems to be towards winch-hauled bogies, and I should like to have the authors' comments on this trend.

I should also like the authors to enlarge on why it is that on a cold mill set on hard control there is more counteraction of speed effect than with the soft control.

Mr. **G. Ovens** (McLellan and Partners) said in reply: The first question asked by Mr. Evans—and Mr. Christie's last—concerned the application of automatic control for screws. Ward-Leonard drives are used on the screws of the 5-stand cold mill at the Velindre works of the Steel Company of Wales with the aim of being able to apply closed-loop control of the screws, particularly of the first stand, should automatic gauge control be required. This was not the only reason why a Ward-Leonard system was adopted; the other reason was to avoid the very frequent operation of fairly large contactors as with a rheostatic system. Contactors were used with 'on–off' control, but these were in the Ward-Leonard field circuits of the individual generators, of which there is one for each screw motor—ten in all for the 5-stand mill.

Answering Mr. Brown on this same subject: the 3-field generator frames were not laminated, but were of standard design. The response of the 3-field system was almost as good as with rheostatic control on another similar mill. We were not concerned with enhancing the performance under manual control, but we wished to have Ward-Leonard available for automatic gauge control and at the same time to benefit from the lower maintenance.

Mr. Evans referred to the cost of the Ward-Leonard system compared with rheostatic. Our experience has been that the initial cost is not higher, taking everything into account. That was one reason why we used the simple 3-field design of the Ward-Leonard generator. Maintenance costs have been shown to be very much less with the Ward-Leonard arrangement.

Several speakers mentioned the possibility of designing and building larger magnetic amplifiers. The tendency in the future will certainly be in that direction. In fact at present many small Ward-Leonard drives are supplied by magnetic amplifiers. Even in the control systems, fairly large magnetic amplifiers of 2 or 3 kW output capacity are in use supplying the fields of large generators.

Mr. Williams' remarks about the assessment and calculation of the generator capacity for feeding the auxiliaries of a primary mill are very interesting. The size of such generators and of the motors themselves, both for mill auxiliaries and for processing lines, could form the subject of an additional paper.

The figures which Mr. Williams queried, for the saving in capital and running costs by reducing the size of the two driving motors, are actually thought to be on the conservative side. A reduction such as this is reflected back right along the line; and the figures we quoted included the saving in the supply system and in civil costs.

Mr. Brown mentioned the omission of contactors and the use of a controller operating directly on the control fields of magnetic amplifiers. Mr. Dodd touched on this very interesting development in introducing the paper.

The qualities of saturation of the magnetic amplifier can be used with suitable biasing to operate on generator

control and to transfer smoothly to shunt-field control without interrupting any circuit.

Mr. Jenkins raised the question of closed-loop control of speed of the individual stands of a tandem cold mill. A mill with such a drive is working in this country under speed control and where load droop is added. The individual speeds are made to conform to a reference and an adjustable droop proportioned to the load current is added. Most other mills operate on the controlled voltage system with an inherent load droop which can be reduced or increased by altering the amount of current signal fed into the control of generator voltage.

It would be interesting to know from B.I.S.R.A. whether, with the scaling down of the tiny cold-strip mill referred to by Mr. Jenkins, the speed effect is noticeable at these lower levels of speed. 10 ft/min is a little different from 4500 ft/min.

Mr. Schwarz introduced the idea of using a buck-boost generator on a rectifier-fed system. This is an interesting thought but I have not sufficient practical experience of the application to comment on it other than to say that there are some applications where this arrangement might be valuable.

Mr. Schwarz asked why 400 c/s was used for magnetic amplifiers. This probably arises from service practice and is an integral number of times greater than the standard frequency.

The point made by Mr. Emms about complexity is a very real one. Many of the control systems are, I agree, largely Chinese puzzles. But this is more than often necessary to meet operational requirements. Transducers for speed and position measurement are at present developed for connecting directly to magnetic-amplifier fields and experience shows that they are as good as those suitable for working with electronic equipment. Mr. Emms also mentioned the susceptibility of mercury-arc rectifiers to temperature. It seems to us essential for satisfactory and continuous operation that the rectifier rooms should be air-conditioned with control of temperature.

Mr. Levetus referred to range and efficiency of the Ward-Leonard system. With generator-voltage control there is really no limitation to the speed range, but with a constantly running motor-generator set, the efficiency naturally falls with voltage. There are some voltage-dependent losses so that the relationship of efficiency to voltage is not linear.

With regard to the stiffness or the inherent speed droop with load on a Ward-Leonard system, the natural tendency is for the percentage droop to increase as the motor speed is lowered by generator-voltage control. In fact, the r.p.m. droop can be looked upon as being substantially constant. With current feed-back the droop can, however, be characterized so that it can be kept at a constant percentage irrespective of speed or generator voltage.

Mr. Levetus also asked about the relationship of stored energy to power in Ward-Leonard rotors. There are two rotational systems in the Ward-Leonard arrangement: the driving motor and the generator set. As Mr. Brown mentioned, there is a case for having a relatively high inertia in the motor to withstand impact loads. Furthermore, a relatively higher generator set inertia is required in some cases as, for instance, in the Ilgner set to even out the energy demand on the supply system.

Mr. Christie and Mr. Jenkins mentioned the 'hardness' of control of a cold-mill drive. A mill drive with accurate speed control is in fact extremely hard and if there is any externally imposed effect, such as the speed effect, the mill will continue to maintain gauge but the interstand tensions will alter, perhaps to dangerously high values.

In other words, a mill with hard control will counteract the ' speed effect ' disturbance by calling for a rise in tension. On sheet mills where a rise in tension can be permitted and where the speed effect is not so noticeable, the linear speeds being less, operation with a hard mill can be permitted. On a tinplate mill, on the other hand, running at high speed on thin material, there is a danger of strip breakage if the mill is too hard.

Mr. **J. T. Jones** (English Electric Co., Ltd.): Most of the points in the paper and in the discussion have referred to the larger drives. For variable-voltage control of smaller drives, say 50 to 500 h.p., different considerations arise. While economic running favours the use of rectifiers for the larger drives, for smaller drives the saving of power as a percentage of total works load is negligible. First cost, however, is usually seriously considered and, providing the performance requirements are suitable, the rectifier conversion is frequently cheaper. The lack of rotating parts favours the rectifier from maintenance considerations.

While the problems of regenerative braking by armature reversal have been considered for large reversing mills, this principle has been applied on smaller drives without difficulty. Instead of the very special armature-reversing switches, standard power contactors are used on the smaller drives enabling full torque braking to be applied at all speeds for little more in cost that conventional dynamic braking.

One type of drive which does not lend itself to the application of rectifiers is that concerned with continuous strip where a smooth transition from motoring to regeneration or vice versa is required. An example is a pay-off reel normally applying back tension which needs motoring current for acceleration. While back-to-back rectifiers could be used, they would not be economically justified.

Where high-accuracy fast-response controls are required, these can often be more readily applied to the grid control of a rectifier than to the field of a generator.

Mr. **R. D. Langman** (United Steel Companies Ltd.): Much has been said in the paper and discussion about the design of the motor and certain other parts of the control system. I should like to make a plea for the control-system designer. It is easy to design a system which can be described in terms of linear functions. Most designers of the normal type of magnetic amplifier and Ward-Leonard control closed-loop systems have been able to include the non-linearities describing current limiting and amplifier saturation, but when designing control systems involving mercury-arc rectifiers the problem becomes very different. Rectifier output is a sinusoidal function controlled by grid angle. This leads in turn to difficulties in describing the mechanics of its dynamic performance.

Analogue-computer techniques aid analysis, but there are many difficulties in representing the mercury-arc rectifier by straightforward techniques. I should like to ask whether the authors know of any means of overcoming this design problem for mercury-arc rectifier control systems, other than by actually building the control system to data based on power requirements only.

My second point concerns the simultaneous control of generator voltage and field current. Most Ward-Leonard control systems which incorporate field control infer open-loop control of field. If we try to obtain continuous control of field current, a tendency to sympathetic oscillations often arises between the two controlled variables. If the load-torque characteristic

between demanded load and speed is known it would be possible to infer a feedback function which is capable of matching a field current for a given series of conditions at any instant in the control period of such a control scheme. Have the authors any experience of such systems applied in the steel industry?

Mr. **J. V. Woods** (Laurence, Scott & Electromotors Ltd.): I wish to comment on the constant-current system for obtaining constant tension on reelers. As stated by the authors, inaccuracies are encountered as a result of the variations in gear and motor efficiencies, while other deviations from the predetermined constant tension are caused by the effects of friction and inertia.

When dealing with heavy-gauge material, the subsequent deviations from constant tension are often not of great importance since their magnitude is small in comparison with the total power requirements for reeling. On the other hand, when handling light-gauge strip, the power level for reeling is lower, whereas the inaccuracies remain substantially the same and thereby constitute a higher percentage of the total power requirements.

Using such a device as the 3-roll tensiometer for the purpose of obtaining a signal corresponding to the strip tension, the reeler-motor output may be controlled to give a tension accuracy which is probably unapproachable in practice on normal constant-current equipment.

On the relative use of variable frequency a.c. or variable voltage d.c. on steelworks auxiliaries, the a.c. approach using variable-frequency induction motors has the limitation that wide relative speed adjustment between the various drives is not possible when all motors are supplied at the same frequency. On some applications this can be a drawback. On the other hand on group drives, such as strip run-out tables, on which all motors have to run at the same speed, the a.c. solution has definite advantages in providing a simple means of achieving this requirement without the inherent difficulties of temperature error and of speed matching encountered on d.c. equipment.

On applications such as strip-processing lines where the strip is handled simultaneously by pinch rolls, levellers, and edge trimmers, only a very small amount of relative speed adjustment is normally required, but a comparatively wide degree of relative torque adjustment is necessary in order to pre-adjust the strip tension between drives. In such instances, induction motors may be supplied with variable frequency for obtaining a variable linear strip speed and stator voltage control may be used on the individual motors as a means of influencing the slopes of their speed/torque curves to obtain a small amount of speed trimming and a large amount of relative torque trimming.

On roller-table drives the tendency was originally to use d.c. motors with variable-voltage control, but it was later realized that the a.c. induction motor, supplied with variable frequency, provided a considerably simpler and cheaper solution. Parallel progress on these lines was made in this country and in the U.S.A., but the inherent difficulties of speed response and voltage regulation on the variable-frequency motor-alternator sets imposed limitations on the a.c. equipment. In cases where low roller speeds were required the choice lay between the use of large, expensive, low-frequency alternators and of motors having large numbers of poles and poor performance.

For these reasons there has been a tendency in the U.S.A. to revert to the use of more expensive d.c. motors on roller table drives. In the U.K., however, we have been fortunate in having at our disposal self-propelled frequency convertors giving variable frequency outputs and also other types of frequency convertors capable of providing very low-frequency outputs, with the result that considerable further progress has been made in the use of a.c. induction motors on such drives. By the use of very low frequencies it has been, moreover, possible to drive rollers direct, without the use of gearing, at very low speeds which for the most part are unobtainable on d.c. motors.

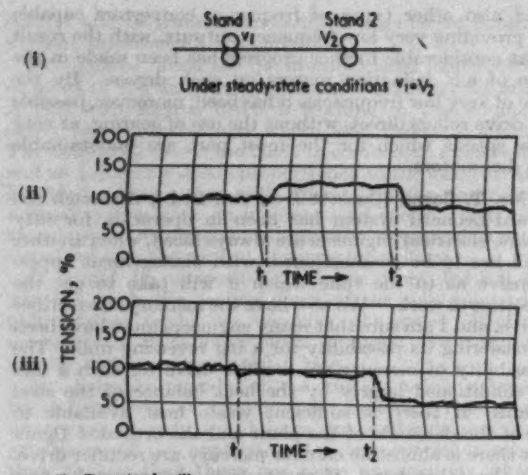
Mr. **T. Coxon** (Consett Iron Co., Ltd.): Although the Ward-Leonard system has been in operation for fifty years, electrical engineers are always faced, when another mill has to be commissioned, with management apprehensive as to the time which it will take to get the electrics to work. We now have the mercury-arc rectifier drive, and I am sure that many engineers must have been considering its possibility for a big reversing mill. The feasibility of mercury-arc rectifier drive for such a mill is conditioned largely by the heat balance of the steel plant. If there is sufficient waste heat available to meet the demands of the plant and the orthodox Ilgner set there is almost no case for mercury-arc rectifier drive. On the other hand, if those demands cannot be met without assistance from the supply undertaking it is a question of whether the undertaking can meet the special requirements. I think that the supply undertaking must face up to meeting the requirements of mercury-arc rectifier drive, as is done on the continent, where the systems are no greater in capacity than our own.

There is no doubt that the savings are considerable, and I believe that the capital cost is not, as has been stated, higher, but lower. There may be a case, depending on the particular plant and its future development—that is, if it can be seen that a growing electrical load will be beyond the plant capacity—for bringing in the supply undertaking to run in parallel with their own station and so meet peak demands. We as electrical engineers do not doubt the ability of the manufacturers to meet all requirements, and particularly the requirements of the operational people, and we do believe the oft-repeated protestations of the manufacturer that the gear will work ultimately.

Mr. **H. Gill** (B.I.S.R.A.): It may be of interest to say something about the work we are carrying out at Sheffield on the model tandem mill mentioned by Mr. Jenkins. This investigation is directly concerned with the effects of the mill characteristics, both electrical and mechanical, on the overall performance of a tandem cold-strip mill; and while this work is still in its infancy, there are several points of interest to this meeting.

In reply to Mr. Ovens' question about the speed effect, the answer is that there is no appreciable speed effect on the model. We built the mill to roll slowly for several reasons, but principally because we wished to study transient behaviour at our leisure without the encumbrance of using high-speed recording apparatus. To avoid trouble with shape control, we scaled down appreciably on the strip width which is only $\frac{1}{4}$ in. This had the additional advantage of reducing the size of the drive as the horsepower required is directly proportional to the strip width.

The investigation is primarily aimed at studying the type of characteristics necessary to provide the maximum inherent regulation within the mill as a unit rather than the alternative of designing closed-loop systems to control every variable. We have become interested in the problem of maintaining constant interstand strip tension when the gauge is controlled by screw adjustments. The difficulty of applying automatic gauge control to a tandem mill is that the presence of interstand strip tension makes it impossible to treat each stand separately as any adjustment to a stand alters



(i) Two-stand mill
(ii) Both drives with zero speed regulation
(iii) Speed regulation on stand 1, 7·5%, on stand 2, zero

Fig. A—Effect of motor characteristics on tension transients

the magnitude of interstand tension which in turn affects the outgoing gauge of the other stands.

An example of the way motor characteristics affect tension changes in given in Fig. *A*. This shows two records of tension transients in which the same schedule was rolled on two stands (Fig. *A*i). At time t_1 a screw adjustment was made to stand 1 to increase the outgoing gauge and at the instant t_2 the thicker material entered stand 2. The only difference between the record was that in Fig. *A*ii the speed regulations of the drives of both stands was zero, whereas in Fig. *A*iii stand 1 drive was adjusted to allow a full load speed regulation of 7·5%.

In the first example (Fig. *A*ii) the roll speeds are unaffected by changes in torque but at all times the strip velocity entering stand 2 (V_2) must be equal to that leaving stand 1 (v_1). As stand 1 screws are raised the reduction in forward slip tends to reduce v_1 and the tension rises until v_1 and V_2 are again equal at some lower value.

The above conditions persist until the thicker gauge enters stand 2. When this happens, the increased reduction causes an increase in backward slip on stand 2 with a fall in entry velocity (V_2) and of tension. The final steady tension is slightly less than the initial value.

In the second case (Fig. *A*iii) as stand 1 screws are raised the reduction in torque allows the roll speed to increase by an amount which more than compensates for the slip change; v_1 thus increases slightly and the tension falls. As a further fall in tension results from the entry of the thicker material into stand 2, the final steady state tension is appreciably less than the initial value.

Mr. G. Ovens, adding to his earlier reply, said: Mr. Langman and Mr. Emms referred to the use of computers. Very good results have been obtained from analogue computers in the design and commissioning of mill drives. The settings of the tension-control system on the 5-stand mill to which I have referred were calculated on an analogue computer and were applied on site with almost immediately perfect results as regards stability and accuracy of control. There is a difficulty as Mr. Langman has pointed out, when dealing with non-linear quantities and it might be very difficult to set up a mercury-arc rectifier system. There is no doubt, however, that even with mercury-arc rectifiers the various relationships could be assumed to be linear for computation over small ranges.

With regard to Mr. Langman's second point concerning the interaction of generator-voltage and motor-field control, we have had experience where both are used simultaneously. It is not unusual, for instance, on coiling strip to have two closed-loop systems, one for regulating motor voltage proportional to strip speed and the other for controlling motor current to be proportional to the desired value of tension. In this case, however, the voltage control by motor field is relatively slow-acting and need only follow up the relatively slow increase of coil diameter. The current or tension control must be rapid in operation to achieve the necessary accuracy. Our experience has been that there has been no interaction between the systems controlling the two quantities.

Mr. Woods spoke of the disparity between the tension measured by current and the actual tension in the strip. In most tension reel drives we are in fact using the motor as the measuring device and I think it is a little unfair to expect a large d.c. motor to give, on an ammeter, a close representation of tension. When dealing with delicate material such as foil the motor is not a sufficiently accurate tension transducer and the adoption of some device which gives more accurate results is necessary: in fact a tensiometer is required.

As Mr. Coxon inferred, it is the management who pay the piper and who therefore call the tune, and the difficulty to which he refers is a very real one and will require the co-operation of the steel mill engineers and of the management if we are to go ahead.

The Chairman (Mr. W. M. Larke): I am delighted that this discussion has ended on the note of costs and paying the piper. That is one of the major problems which we shall have to face. Do we really need these wonderful motor houses? Do we in the industry know all the things that we need? Have we investigated them? These are major problems for the designers of electrical equipment and which those of us in the iron and steel industry ought to face. I know that I have the support of B.I.S.R.A. on this. There is an enormous expansion all over the world in this industry, and the world cannot afford an expenditure of £100 per annual ingot ton in investment. We engineers have to think of all these things, and costs must be ever present in our minds.

DISCUSSION ON TRANSLATOR CONTROL

This discussion was based on the paper by W. N. Jenkins, entitled **"Translator Control,"** which appeared in the February, 1958, issue of the *Journal* (vol. 188, pp. 157–168).

Mr. W. N. Jenkins (British Iron and Steel Research Association) presented his paper.

Mr. J. Poole (Steel Co. of Wales Ltd.): First in regard to program control of input signals to closed-loop systems, the author states that punched cards were not successful. I should like Mr. Jenkins to amplify that a little, because a lot of them are used in the U.S.A. and we are told that they are quite successful.

The second point is that in program control, tape handling must also be difficult, as all program selection must be done by machine. The operator cannot handle a large number of tapes while he is working normally,

and therefore the tapes must be readily available and selected by some method of control switch, push-button, or other device.

With regard to translator control of a mill (Fig. 5) I feel that the operator would not concentrate and this might cause him to miss an incorrect rolling cycle, resulting in a very bad smash.

In a completely controlled mill much equipment must be exposed to dirt, scale, steam, water, and heat, which are bound to be troublesome. I should like to know how these problems are overcome when they occur all over the mill.

Another point about translator control is that the operator must be able to go back to manual control very quickly if something goes wrong with the rolling operation. It is probable that when something happens in the middle of a program-controlled cycle, the operator has to come back on to manual control, finishing the ingot on hand operation and carrying on with the programming device when the next one appeared.

In regard to the translator equipment itself, different manufacturers have their own ideas on how programs can be put in. Some offer switches, telephone dialling devices, push-buttons, rheostats, cards and tape, etc. I would ask whether the equipment has to be of the telephone type. There are various circuits being developed today which give ' go ' and ' no-go ' features, and surely these could be applied as part of this control to overcome the difficulties which are bound to arise with telephone-type equipment.

The translator must provide the 'no-program' warning which is indicated in the paper, because an operator might put in the wrong setting and in some cases he is not putting this program in until the ingot is within the mill. Therefore time is very limited. You cannot have ingots going cold while he makes up his mind what to do. In those circumstances, he would go back to manual control and carry on as I described earlier. Another feature about a ' no-program ' device is that it could be used in certain circumstances as a fault detector. If you have drives which are rather complicated in their control, lots of devices have to be right, and something wrong in the control chain can cause a great deal of trouble. Manufacturers provide fault-finding circuits in their equipment, but these are usually manually operated. Somebody has to be told that something is wrong; the electrician has to go and find out what has happened—and all that takes time. If a device could be used to work continually on the control scheme and give a warning and some indication of where a fault has occurred, it would be an asset.

Translators could be used on blast-furnace skip-hoist controls, providing a sequence control from either scale car, furnace platform, or any other convenient point which might be available. In a mechanical handling plant the whole system of conveyors could be controlled from a central raw-material office. That sort of thing is well on the way today. We have large conveyor installations in various parts of the country, in many cases controlled from a central office where there is a mimic diagram indicating the direction and number of conveyors running at any time. The system of control is for the raw-material controller to phone up operators who are at control points in various parts of the plant, give instructions to them, and then check on the mimic diagram that his orders have been followed.

The translator could also be applied to the roughing train of a hot-strip mill. There it could be used to set up all the various parts of the mill when a change in rolling program takes place. These changes happen quite often. It is necessary at that time to set up horizontal roll gaps in the various mills and vertical roll gaps where they apply, the side-guards on the ingoing side of the mill, the squeezer (if there is one), and also, of course, table speeds. They have to be set up individually when there is a change and it is a good idea, I think, to consider this being done centrally on a program basis, provided of course that the schedules are fairly routine.

In regard to the strip-mill train, the same remarks apply. A central control could be set up and this could control all sorts of things, including run-out tables and cooling equipment. One thing must be considered, and that is that on a wide hot-strip mill there is the problem of shape during rolling. If a mill is set up and the conditions between tandem mill stands are correct, the material passes through quite nicely, but if one-stand screwdown is changed you can get a waviness of edge set up which can be corrected only by individual screwdown adjustment across the mill and followed through the train to the end. That works against the central control of screwdowns and will have to be carefully considered.

In a cold mill, translators could be used for monitoring circuits. Translators could be used for office work, such as scheduling plant operation and other routine types of jobs.

Summarizing, when applied to steelworks control the translator, to be consistent, must have the other conditions around it stable. On a primary mill, it must have good soaking-pit operation to limit the number of variables that can come into the material passing through the mill and therefore give the programmed automatic control a good chance of working. Finally, it must not be terribly expensive.

Mr. **W. N. Jenkins** (B.I.S.R.A.): It is interesting to hear that there are possible applications for the translator which we had not ourselves thought of.

We started on the work which led to the translator when it was realized that the means of programming rolling mills available at that time were not entirely satisfactory. Two members of the Electrical Section of B.I.S.R.A. visited several mills on the Continent with automatic screwdown control and in their report wrote that a punched-card system had been installed in one plant and then taken out of operation after a very short period, owing to delays in changing cards and in handling damaged cards. Another scheme with plug-boards had also been taken out of service.

I would say that punched cards and punched-card machinery are considerably less robust than the usual run of pulpit equipment, and the handling of punched cards requires a completely new standard of manual dexterity and care. The translator pulpit equipment, on the other hand, is simply a setting desk which can be made very robust, by using the same type of control switches that already exist in mill pulpits.

I feel perfectly happy about the standard of robustness and reliability of the post-office equipment from which the rest of the translator is constructed. It is wise to keep such equipment away from the mill and this is usually possible. Under reasonable conditions very long maintenance-free service can be expected. We have had about 75 stepping switches working day and night in a steelworks for over a year and they have given very little trouble. A motor uniselector has also been trouble-free for the same length of time.

Mr. Poole said that the Steel Company of Wales had given up using post-office equipment and I gather that the reason was that maintenance personnel were not available at all times. He said that they have now gone back to the old-fashioned sort of equipment. Of

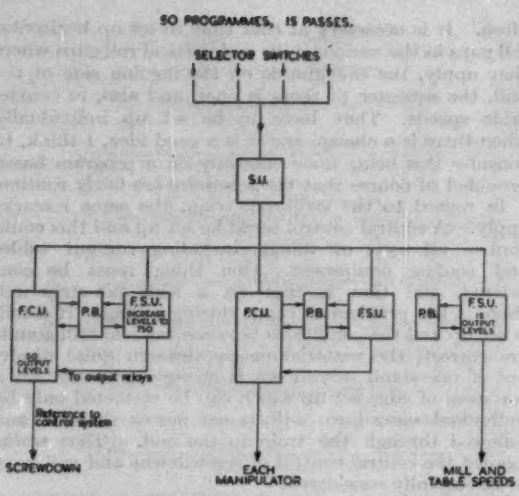


Fig. A—Block diagram for automatic programmer equipment

course, they could have gone forward and used more of the new equipment, in which case it would have been worthwhile having an organization to take care of it.

I did not altogether agree with Mr. Poole when he said that a translator must have stable conditions in which to operate. A properly designed translator will have switches to set up *all* the relevant variables, so that in the case of the primary mill, observable variations at the soaking pits can be taken into account by a switch provided for the purpose. No other program equipment, as far as I know, can deal with variations in such a speedy and simple way.

Where the type of programmer adopted is based on the use of uniselectors, that is the translator, it seems to me that one of the most significant features of the equipment is the facility of being able to select the required program by means of switches marked in terms of initial dimensions or weight, required final dimensions, temperature, type of material, and any other factors which would cause a variation of program. Most of the other methods at present in use are based on the setting up of screwdown position pass by pass. As the author points out this is laborious particularly when the equipment controls more than the screwdowns alone.

Translator-type equipment can of course be extended to control all the movements or functions on a mill. On a typical mill the functions which would need to be controlled are the positions of the screwdowns and two manipulators, and the speeds of the main drive and roller tables. It is then a short step to introduce sequencing relays actuated from, say, photocells determining the position of the piece being rolled, in order to make the mill operate completely automatically. As stated by the author the operator would then act as a supervisor ensuring that the mill ran properly. For example, as previously mentioned, a control which trims the position set by the programmer for each manipulator would be provided for straightening a bent piece, together with an over-riding manual mill-speed control to overcome either fishtailing or false entry.

It is both practical and convenient to unitize any programmer equipment so that standard units can be manufactured. Thus for each application a different combination of these units would be required depending upon the type of mill, the program storage required, and the number of functions to be controlled.

With the translator equipment described by the author the input uniselectors *A*, *B*, and *C* combine two duties. They store programs, and they select the program determined by the input switches. Thus, since one uniselector track is needed for each input selector switch, the maximum number of passes which can be stored in any particular equipment depends upon the number of input switches. That is, if five selector switches are needed, the maximum number of passes possible for one uniselector is 11 since the total number of tracks is 16.

By separating the operation of program selection and program storage, it is possible to unitize the programmer equipment. One unit containing a program storage motorized uniselector together with an output motorized uniselector would be used to control each function (i.e. screws, manipulator, etc.). To control all these function control units, a single selector unit containing a motorized uniselector marked or homed by the program selection input switches, together with the ratchet uniselector for selecting passes, is required. Thus the sole duty of the motorized uniselector in the selector unit is to select the program determined by the input switches, and transfer this uniselector position to all the program storage uniselectors in the function control units. By this method 15-pass programs can be stored independent of the number of input switches, and the number of uniselectors required for any particular application is normally reduced. The duty of the single ratchet uniselector is to select pass-by-pass the required settings for all the functions.

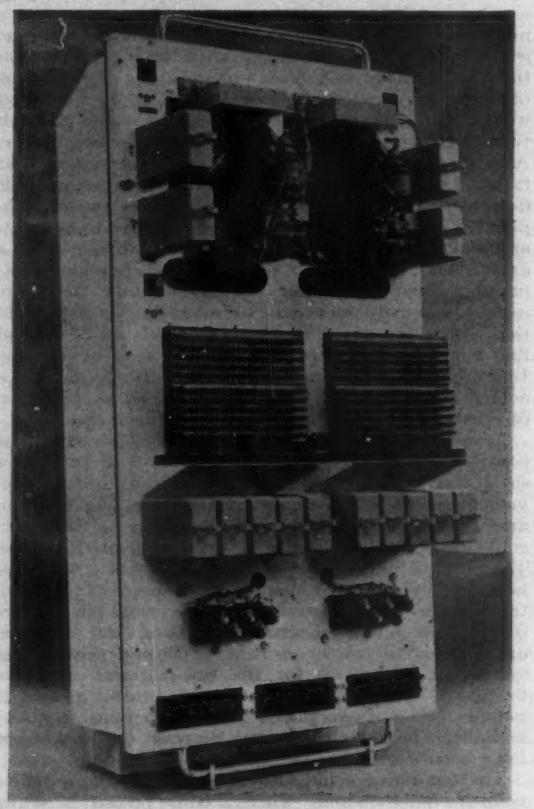


Fig. B—Front view of typical standard unit (front cover removed)

Figure *A* shows a simple hypothetical system in block diagram form. The single selector unit is governed by input switches and controls in turn both program and pass sequence selection for the three function control units for manipulators and screwdown, together with a simpler form of function control unit for speed.

Figure *B* shows one of the standard units with the front cover removed, and Fig. *C* shows a typical installation using these standard units. It will be seen that the use of mounting hooks and connecting plugs permits quick replacement should this be required for maintenance, wiring-in programs, etc.

In any programmer equipment based on the translator it is important that a simple reliable method of wiring-in new programs is provided. The tagboard in the unit shown in Fig. *B* enables this to be carried out using standard cable forms connected between this tagboard and the program storage uniselector. No programs are shown wired in.

Mr. **F. B. Levetus** (Keelavite Rotary Pumps and Motors Ltd.): In consideration of such high-performance closed-loop servos (as positionally controlled screwdown gears demand in many cases), the speed of response is sometimes critical and I wonder if enough consideration is given to the use of hydraulic rather than electric motors. Hydraulic motors suitably controlled can offer the precise equivalent of Ward-Leonard systems, and eliminate certain inherent disadvantages. In particular I would refer to the low inertia of the rotating parts of hydraulic motors. This may be a disadvantage sometimes, but it is an enormous advantage when dealing with positional controls, and the ratio is not perhaps always appreciated. The ratio of torque to inertia of an hydraulic as compared with an electric motor may be between 200 and 300 times in favour of the hydraulic motor. This in itself would help to solve certain fundamental positions of limit stops, because with so low an inertia in the rotor operating a driven member itself without inertia, no damage will result from impact if limit stops are overrun. In addition, the field of control called for by screwdown drives is not entirely unlike work which has been done with hydraulic motors, and I would quote as an example an installation to control the flexible walls of a very large wind tunnel.

In the field of aeronautics there is always a suspicion that equipment is short-lived, but in this case it is an apparatus which has to operate, if possible, virtually continuously, and represents a capital investment of approximately £9 million. It must therefore be reliable and it must continue to operate indefinitely. In this case, I think it can be said that an analogy would be the control of all the screwdown gears of a 30-stand continuous mill. There are 30 pairs of screws which manipulate the shape of the walls of the tunnel, taking loads of plus or minus 30 tons maximum, with strokes of the order of 30 in. The walls must be positioned, regardless of load, to a specified accuracy of 5/1000 in. The accuracy obtained in practice is indicated by a full response to a signal of 1¼/1000 in. This is obtained by the use of simple hydraulic motors controlled by positional gear, controlled in turn by a system of uniselector switches, controlled in turn from an overall punched-tape signal.

Mr. **D. F. Nettell** (Powers Samas Accounting Machines Ltd.): Mr. Jenkins mentioned that two members of B.I.S.R.A. toured the Continent and reported on the question of punched cards for controlling rolling mills. I was one of them.

The report concluded that punched cards were unsuitable on the grounds that they were insufficiently flexible and were difficult to handle. I would like to discuss some recent developments in punched-card machines which should get round these difficulties and which could form a useful output mechanism in conjunction with translator control. I would say at once that these developments in no way conflict with the application of the equipment described by the author, but rather extend the use of such a control system to fields other than that of rolling-mill control.

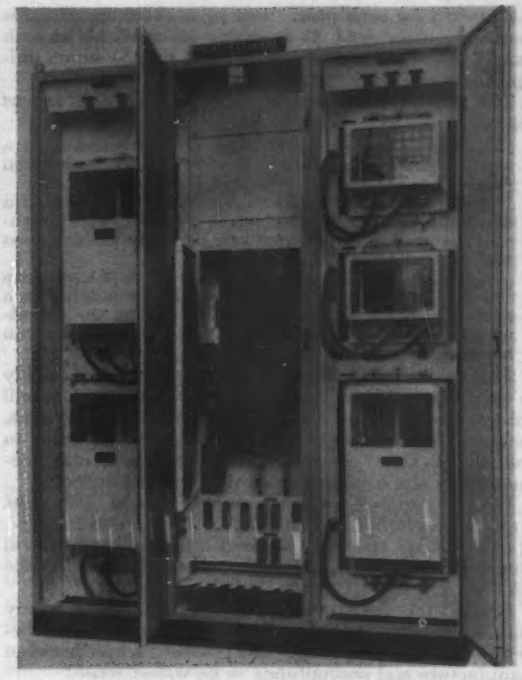


Fig. C—Typical programmer cubicle with mounted standard units

There have recently been developed a number of machines for sensing punched cards and converting the information they contain into electrical signals. In the machines with which I am concerned, the complete card of 65 columns and 12 rows is sensed while stationary and contacts are closed corresponding with the holes punched in the card.

It is most unlikely that anyone will want 65 decimal digits of information at any one time in a control system.

In rolling-mill screwdown, 3 decimal digits are usually sufficient. The card may therefore be divided up into 21 fields each of 3 columns.

At the front of the machine there is a magazine which can hold up to 100 cards. On receipt of an electrical pulse a card is fed from the bottom of the pack into the sensing head and the holes in the card cause the appropriate contacts to be closed. On receipt of the next pulse the magazine drops and the card is ejected on to the top of the pack. The magazine then rises and another card is fed from the bottom of the pack and is sensed.

In this way a given number of cards can be circulated any number of times through the machine and each sensed in turn.

In applying this principle to the translator control described by the author, the machine would replace the motor uniselector of the output section. One card would be provided for each pass and the machine would

feed a card for each pass. But since there are 21 fields available on the card, 21 programs are available at each pass. The program used is selected by the input uniselector of the translator.

The outstanding features of such a scheme are as follows:

(i) Card handling by the operator is reduced to a minimum. He has only to insert the pack for a given run

(ii) The flexibility of program selection which is a feature of translator control is retained, i.e. instantaneous change of program can be made at each pass without handling cards

(iii) The complete program with all its 21 versions can be changed very quickly merely by putting in a new pack of cards. Alternatively, during the experimental stages of a run, one setting in a program can be changed by replacing one card.

This flexibility of changing complete programs quickly is not necessarily an advantage in many rolling-mill control problems, since the pattern of rolling programs, including the variations, may continue for months on end and in these conditions the situation is met adequately by the equipment described by the author.

Where punched-card equipment would be most applicable is in batch production where several hundred of one product are manufactured one week and several hundred of an entirely different product are made the next week.

Finally, the use of punched cards for controlling any machine or process opens the way for integration between works and the office and provides a link between manufacture and accountancy in its widest sense.

Mr. **Jenkins**: How long does it take to change cards between passes?

Mr. Nettell: Half a second.

Mr. **Jenkins**: I think that should be quite fast enough. The last point made by Mr. Nettell about the bridging of the gap between the office and the mill is a very important one, but I am not sure whether the ultimate aim of a punched-card system, i.e. one card produced in the office per job, is applicable to rolling-mill control. It does mean that the selection of programs, in part at least, must be made in the office, and I would rather see the roller man in complete charge of the potentially dangerous operation.

A certain amount of interchange of information can occur between the office and the mill with the translator as it is already conceived. The setting switches on the desk can be integrated into a performance recorder system in order to bring back to the office data about what has been rolled and how long it took to be rolled.

Mr. **D. W. Prowse** (British Thomson-Houston Co., Ltd.): The translator is only one example of a method of programming. This particular method does not appear to be very flexible. The programs are built into the translator during manufacture, each program being associated with particular wired connections. Any modification or addition to these programs would entail disconnecting, reconnecting, or adding more wires. Such a process does not appear to be very desirable.

For a screwdown application with which I am familiar, the programs will be stored on tape. The tape-reading equipment will be duplicated so that while one ingot is being rolled, the schedule for the next one can be set up in readiness. New schedules can be included into the program quite easily by standard tape-punching methods. A further advantage with the overall scheme for this screwdown control is the ability to superimpose semi-automatic control. This is in the form of draft selection by keys in the pulpit. With those keys the operator can set a repeatable draft which is automatically arranged to be cut out when the finished ingot size has been reached. The information fed into the system by the keys could be modified to feed in a biasing signal which could be superimposed on the schedule read from the tape. In this way compensation for roll wear could be obtained. How can such compensation be made with translator control?

The use of potential dividers and contactor selection for position reference appears to limit the minimum reference adjustment. Synchros are more commonly used in remote-position control and I would like to know whether the translator can be easily associated with a synchro remote-position control system on a plate mill.

Mr. **Jenkins**: The object of the operator's setting desk is to set in those very changes of program which Mr. Prowse mentioned. For example, the material being rolled often influences the scheduled program, and in such cases a switch has to be provided for the operator so that he can select the appropriate program, taking into account the material being rolled. Similarly, if roll wear is a significant factor then there must be a switch provided on the input desk so that the appropriate program changes can be made. It is possible that the number of programs will be large when all the relevant factors have been taken into account, but there is much that can be done to conserve storage capacity by sectionalizing programs, i.e. by making two or more serial programs from one schedule connected through common or 'pivot' settings.

As regards the building in of new programs, this can be arranged by a soldering technique, or by means of plugboards. Bearing in mind that new programs would be added only infrequently, I think that the time spent in program insertion would not be significantly different from the time spent in punching the corresponding tapes. Certainly the amount of labour in soldering in a program is not great—about a quarter of an hour per program, I should say. With a reasonable amount of standby equipment, it would not be necessary to stop rolling to insert programs.

Before the application of any form of program control, it is advisable first to make an investigation into the settings made manually by the operators. It should be possible to derive, in advance of the application of translator control, the optimum rolling programs for every often-repeated condition, based upon the best rolling practice by the best operators, and it should not be necessary to tamper with programs after insertion.

Mr. **R. Green** (United Steel Companies Ltd.): I wish to make two specific points in relation to the B.I.S.R.A. equipment. First of all, there is a psychological point concerning the presentation of the concept of programming and translation. The equipment must be demonstrated to management and operatives in such a way that they can appreciate the physical facilities offered. In this direction I suggest that the concept of translation, important as it is, is rather obscuring the issue of individual program storage, and I would advise that the equipment be demonstrated first and foremost as a program storage. Only when this has been accepted and understood should the concept of translation from ingot and bloom details to a specific program be introduced. Practically, the panel illustrated in Fig. 2 of the paper could be replaced (in the first place) by a single control knob having say 50 positions simply numbered 1 to 50. Each position would represent a unique program. After this had been demonstrated the panel of Fig. 2 could be used.

My second point deals with the flexibility of the equipment. The widely used American system of program control, notably the E.C. and M system, has been criticized because of its bulkiness, its old techniques, and its lack

of flexibility. Some of the criticism can be justified, but the question of flexibility requires closer examination. In the American system each individual pass of a sequence is set up on an individual rheostat. The equipment is usually located quite close to the operator who, very quickly, can adjust the passes by quite minute amounts. That is invaluable flexibility and is something that the translator does not possess. It is something that the translator must possess before it can be widely applied, particularly to cogging mills. There are many operational variables that would call for such adjustment, and I will single out one of them, notably roll wear.

To follow the effect of roll wear, consideration must be given to the action of the translator. It gives screw-down control by the accurate positioning of the mill screws. If bearing wear is neglected, that is tantamount to saying that the translator gives accurate positioning of the top roll axis. The bottom roll axis is fixed, so that the translator in effect accurately fixes the separation of the roll axes. The roll gaps are only fixed to the same degree of accuracy if the roll diameters remain sensibly constant, and they do not do so under wear. If the wear were uniform across the roll barrel, simple correction could be made, but unfortunately this is not the case. Figure *D* illustrates a typical pair of cogging rolls with four holes. In a typical 11-pass sequence, the holes would be used as follows: two passes in the first hole, four in the second, four in the third, and one in the fourth. Since the wear must be related to the amount of work that the holes are doing, it follows that there will be more wear on the diameters of the second and third holes than on the fourth. It follows that the diameters of holes 2 and 3 are going to get progressively smaller and the roll gaps progressively bigger at a faster rate than is the case with holes 1 and 4. Consequently the screw-setting program must change under the direct control of the operator.

During roll dressing it is easy to bring the individual diameters back to a datum or reference diameter, but the same is not true of the pass widths. The roll collars wear in much the same way as the diameters wear, and it will be appreciated that it is not possible to bring collars back to the same size on dressing unless there is considerable taper down the collar sides, which is not always practicable. Therefore even when rolls have been dressed the diameters will be back to a reference but the pass widths will not, so that the pass widths will depend on the age of the roll. Again, this calls for changes to the stored programs.

Consequently it is desirable that the translator should incorporate ' fine controls ' which can be used instantly by an operator to make small adjustments to individual passes of stored programs.

Mr. **Jenkins:** I do not feel qualified to comment in any way on what Mr. Green has said, except to say that in my opinion the necessary flexibility can be provided. I think that it should be possible to specify the wear in some way, because the wear is a result of rolling, and the rolling is carried out in very much the same way all the time. The question arises whether rational controls could be provided so that the operator would be able to set up the variable easily. This is a subject to which we are giving thought, and it is largely a matter of presenting data rather than of program storage. I think that a very large number of combinations of conditions can be taken into account, particularly where there are ' pivot points ' in the programs.

Members will have seen that the number of programs which can theoretically be covered by a translator is the product of the respective numbers of settings each input setting switch can have. Thus if we have two ingot sizes, three working temperatures, seven widths of bloom, and seven depths of bloom, the total number of programs possible is 294. It may have occurred to members that only one or two more input variables might raise this number to prohibitive values. In practice this is not generally so for the following reasons.

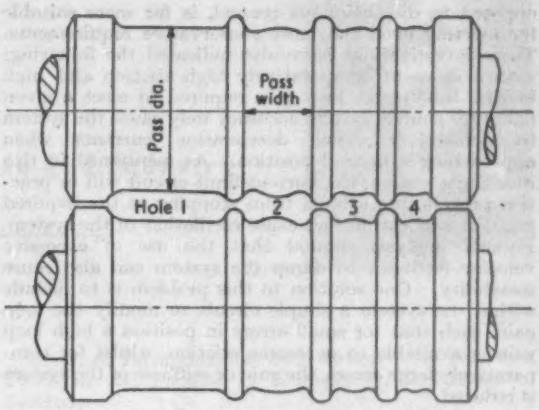


Fig. D—Typical cogging rolls

A good proportion of the total number of programs are impossible anyway.

The total amount of program storage capacity can be minimized by the dodge known as ' sectionalizing '. This can be done in two ways. A program can be subdivided into consecutive sub-programs, or into concurrent sub-programs and dealt with using separate translators but using the same setting desk. Translators can thus be arranged either to operate in series (as in Mr. Jenkin's pivot point scheme) or in parallel, from the same setting desk. The best arrangement for any particular application will be the one involving the least program capacity.

Mr. A. P. Baines (English Electric Co., Ltd.): The problem of compensating for roll wear, raised by Mr. Green, may be met by a method of biasing the output potentiometer of the translator. With such a method there would be available to the mill operator one bias control for each gate. These would be initially set at zero, each being altered as roll wear becomes apparent. In this way the program would be arranged to select the bias associated with the gate being used, and to insert a correction for roll wear in that gate.

In applying a position control to a drive the question of guaranteed accuracy often arises. Tests that I have been associated with have indicated that no great reliability can be placed upon the consistency of friction and load torques to obtain a guaranteed figure for accuracy, particularly over a long period.

An approach is needed to this problem of specifying accuracy and the desired figure for repeatability. The control-system accuracy may be defined as the limits on either side of a desired position within which, if the moving member is stationary, the system will not attempt to correct. This is a firmer figure both for the design engineer to guarantee and as an ultimate gauge of the system, rather than a figure for repeatability which depends so much more upon factors outside the control of the system design engineer.

Investigations of several systems based upon this approach have indicated that continuous control, as

opposed to discontinuous control, is far more suitable for meeting even the most conservative requirements. These investigations have also indicated the following: with a drive of comparatively high stiction and high inertia, the system loop gain required to meet a given figure for control system accuracy may cause the system to demand excessive deceleration currents when approaching a desired position. As mentioned in this morning's session, the current-limit circuit will in practice prevent the system from stopping at the required position and can in fact cause oscillation of the system. Further analysis showed that the use of excessive velocity feedback to damp the system can also cause instability. One solution to this problem is to include within the system a simple circuit to modify the loop gain, such that for small errors in position a high loop gain is available to overcome stiction, whilst for comparatively large errors, the gain or stiffness of the system is reduced.

Mr. **J. Higson** (Dorman Long (Steel) Ltd.): My opinion is, that it is necessary to particularize on the type of mill on which the screwdown will be used before deciding on the type of equipment to be installed, e.g. a cogging-mill drive does not usually require a greater accuracy than say 1 in 100, whereas on a plate or section mill accuracy of a much higher degree is essential on the last pass.

With regard to the use of translators, these could be of various types, and I am not convinced that the punched tape is superior to the punched card under all applications, or even in fact, whether translators are really necessary on some mills. Where different sections can be rolled in the same rolls it is desirable to have some type of translator, but where a change of section necessitates a change of rolls then I feel the translator is unnecessary. At the present time, the company with which I am associated, has installed what is probably the largest preset screwdown equipment in the country. We have two mills operating on five controls each, and the use of uniselector relays in this equipment has been well justified.

Referring to Mr. Levetus' remarks on the use of hydraulic systems, there are in my opinion problems associated with hydraulics which detract from their usefulness in that errors can creep in due to aeration, leakage, and control of valves, 'swash' pumps etc. We have found it necessary on some preset length-measurement equipment of this type to control the scheme by electronics. I feel personally that this duty would be performed more accurately and with more stability if done electrically.

Mr. **Levetus**: In my experience, temperature inaccuracies, aeration difficulties, and instabilities of that kind can be entirely eliminated by proper overall design of the hydraulic system.

The question of electronic as opposed to hydraulic control is not one which I think should arise in general. In my opinion, electronic control is frequently the best control of a hydraulic circuit. I think that on powers above the order of 2 h.p. or so, with a transducer which is of the order of 10 W from signals to power, the combination of electronics and hydraulics covers all the necessary features of a servo system, including response, accuracy, and consistency.

Mr. **Poole**: I should like to clear up a point about the maintenance of telephone-type equipment. We do have a very large section in which there are people who are trained to look after that type of equipment. A lot of them are from the Post Office, but they are not the average day-to-day maintenance gangs who look after the plant. It would mean in effect that if each section of the plant had telephone-type control in it, you would have to have somebody on every shift who understood that equipment. You would therefore have to put them into all the departments for everyday maintenance to be sure that the equipment in that department was adequately covered. That has been our problem.

Mr. **Jenkins**: I do not know whether that need be a problem. Most of the post-office equipment supplied nowadays is arranged to plug in or to be easily replaced, and spares are usually provided so that the plant can carry on until the next morning when the maintenance men are available.

If post-office equipment is not to be used, what can one use? A large number of programs can be stored in two-state devices such as magnetic cores or transistors, or in diode arrays, but the cost is very much higher at present than of a motor uniselector which provides over 800 binary digits of storage capacity for £20.

Mr. **A. Asbury** (English Electric Co., Ltd.): We have modified the idea of the translator in some ways to suit ourselves and our customers. One point which has not been mentioned, is that some method of enabling the customer to learn and refine his program is necessary. This feature has been incorporated in equipment displayed recently in which the translator equipment was arranged to handle the information required to operate a model mill.

The translator system can be compared with a book containing paragraphs corresponding to rolling programs. Each paragraph is selected by appropriate switches and a 'selecting' uniselector. The paragraph consists of a number of sentences each covering the instructions for a control, i.e. screwdown position, mill speed etc. In our development of the system the function of storing this information is carried out by a 'storage' uniselector, while in the system proposed in the paper this is also done by the 'selecting uniselector'.

The pass-by-pass information is obtained by selecting the words of the sentence in turn by means of a stepping uniselector. Finally the information contained in each word is detailed for use in the control system by a detailing uniselector.

It is important to be clear about the possible advantages of translator control. It may not make for large increases in production since output may well be limited by other equipment. It will make it possible to optimize each program to make the best use of the equipment and then obtain this optimum operation consistently. In this way it can pave the way for further advance in integration of control of rolling plant.

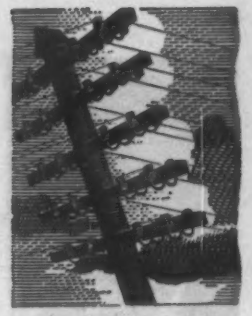
The **Chairman**: We now come to the end of this two-day meeting, and I am sure you would like me, on your behalf, to thank not only the authors of the papers and all those who have taken part in the discussions, but also the staff of the Institute, who have put in a great deal of work.

We must also express our sincere thanks to the Institution of Electrical Engineers for allowing us to hold our meeting here.

May I once again thank all of you for your attendance and for the interest that you have taken and I am sure will continue to take in the Engineers' Group meetings. As this is my last session as Chairman, may I wish the Group all success in the future, particularly under the Chairmanship of Mr. Frank George.

N E W S

Announcements and News of Science and Industry



THE IRON AND STEEL INSTITUTE

Awards to President and Past President

Gold Medals of the Groupement des Hauts Fourneaux et Aciéries Belges were presented at the end of the recent Journées Internationales de Sidérurgie to the Honorary Presidents of the meeting, including Mr. C. R. Wheeler, C.B.E., and Mr. A. H. Ingen-Housz, President and Past President respectively of the Institute.

NEWS OF MEMBERS

Mr. **N. H. Bacon** has retired from Steel, Peech and Tozer, after 47 years' service.

Mr. **J. E. Bainbridge** has joined the Atomic Energy Research Establishment, Harwell.

Mr. **D. R. Baker** has been appointed Assistant Ickles Superintendent (Technical) at Steel, Peech and Tozer.

Mr. **D. B. Bray** is now Manager of the Heat Treatment Department at Steel, Peech and Tozer.

Mr. **A. Dearden** has left the Daimler Co., Ltd., to join the British Cast Iron Research Association.

Mr. **W. Eliasz** has been awarded the degree of Ph.D in the Faculty of Engineering (Metallurgy), University of London.

Mr. **W. Ernest** has left Samuel Fox and Co., Ltd.

Mr. **E. H. Fors** is now a Director of the Morgan Construction Company, Worcester, Mass., U.S.A.

Mr. **J. Hammond** has been appointed Deputy Chief Engineer of Samuel Fox and Co., Ltd.

Mr. **T. H. Harley** is now President of the Vesuvius Crucible Company, Swissvale, Pa., U.S.A.

Mr. **S. T. Jazwinski** has been awarded the degree of Doctor of Science by the Krakow Academy of Mining and Metallurgy.

Mr. **D. J. Mabbutt** has joined the Parker Pen Co., Ltd., as Chief Chemist and Metallurgist.

Sir **Andrew McCance,** F.R.S., has retired from the Chairmanship of the Mechanical Engineering Research Board after serving since 1952.

Mr. **H. Morley** is now Deputy General Works Manager at Samuel Fox and Co., Ltd.

Mr. **N. B. Pilling** has retired from the International Nickel Company.

Dr. **Peter Roderick** has been appointed Assistant Chief Metallurgist of the Steel Company of Wales Ltd., Steel Division.

Mr. **T. W. Ruffle** has left the E.N.V. Engineering Co., Ltd., and is setting up a British office for Ipsen Industries Inc., of Rockford, Ill., U.S.A., manufacturers of heat-treatment plant and atmosphere control equipment.

Mr. **E. Stein** has accepted an appointment from the United Nations Technical Assistance Administration to advise on the testing of hardened steel in Yugoslavia.

Mr. **R. Swinden** has been appointed Works Manager (Services) at Samuel Fox and Co., Ltd.

Mr. **J. S. Terrington** has been awarded the degree of Ph.D. in the Faculty of Engineering, University of London.

Mr. **K. C. P. Wattsford** is now Manager of the Steel Treatment Department of Samuel Fox and Co., Ltd.

Mr. **E. M. Worley** has graduated from the University of Cambridge, and has joined The Steel Company of Wales Ltd., Steel Division, as a research metallurgist.

Obituary

Mr. **Vincent Paul Delport,** B.SC. (*elected* 1930), of London, on 3rd June, 1958.

Dr. **Cecil Henry Desch,** F.R.S. (*elected* 1913; *Honorary Member* 1950; *President* 1946–1948; *Bessemer Gold Medallist* 1938) of Wimbledon, on 26th June, 1958.

Mr. **Victor John Donnelly** (*elected* 1939) of Boksburg North, Transvaal, South Africa, in November, 1957.

Mr. **Colin Gresty** (*elected* 1920), of Wallsend-on-Tyne, on 9th September, 1957.

Professor Dr. Ing. **Eduard Houdremont** (*elected* 1952), of Essen-Bredeney, Germany, on 10th June, 1958.

Mr. **John N. Marshall,** B.S. (*elected* 1950), of Granite City, Ill., U.S.A., on 15th April, 1958.

Monsieur **Jean Raty** (*elected* 1956; *Honorary Member*), Président de la Chambre Syndicale de la Sidérurgie Française, on 20th June, 1958.

CONTRIBUTORS TO THE JOURNAL

D. J. Carney, D.S., B.S.—Divisional Superintendent Steel Production, Duquesne Works, United States Steel Corporation.

Dennis J. Carney was born in 1921 in Charleroi, Pennsylvania and attended public schools in his home town. He gained his B.S. degree in metallurgy at the Pennsylvania State College in 1942, and carried out post-graduate research at the Massachusetts Institute of Technology, where he was awarded the degree of Doctor of Science in Metallurgy in 1949. He also attended the Carnegie Institute of Technology, Colorado University, and the Harvard Graduate School of Business Administration. During the war he worked at the Metallurgical Department of the Naval Research Laboratory and later at the Bureau of Naval Intelligence.

Dr. Carney has worked in the Metallurgical Departments of the United States Steel Corporation's works at Clairton and Duquesne, and for a time he was with the Pittsburgh Steel Company. He has had extensive experience with both open-hearth and electric furnaces at the South Works of the United States Steel Corporation.

For some years Dr. Carney has been a member of the executive committee of the Chicago Section of the A.S.M. and the A.I.M.M.E. He is also a member of the Physical Chemistry of Steelmaking Committee of the Iron and Steel Division of the A.I.M.M.E., and is Chairman of the Publications Committee of the A.S.M.

R. E. Fryxell

N. Galitzine

I. Ljungberg

U. Notini

R. E. Fryxell, M.S., PH.D.—General Electric Company, Pittsfield, Mass., U.S.A.

Robert E. Fryxell was born at Moline, Ind.; after obtaining his bachelor's degree at Augustana College, he entered the University of Chicago, where he was awarded the degrees of M.S. and Ph.D. He worked for three years with the Manhattan Project at the University of Chicago and Los Alamos Laboratories, and later spent four years with the Institute for the Study of Metals at Chicago as a part-time staff member while attending graduate school. Mr. Fryxell, who joined General Electric as a specialist in analytical chemistry in 1950, has been chiefly concerned with chemical analysis problems associated with metallurgy and with the reactions of non-metallic impurities in metals.

N. Galitzine, M.S.—Analytical Chemist, Major Appliance Laboratories, General Electric Company, Louisville, U.S.A.

Nicholas Galitzine was born in 1904 in Moscow (Russia), and educated at the Russian Gymnasium in Russia and Bulgaria. In 1928 he graduated from the Ecole de Chimie Industrielle de Lyon (France) with the degree of Ingénieur Chimiste, and in 1940 he gained his M.S. degree in chemistry from the University of Michigan.

In the same year Mr. Galitzine joined the Transformer Division of the General Electric Company in Pittsfield, Massachusetts and later transferred to his present post. He is a member of the American Chemical Society and the Metropolitan Microchemical Society.

F. S. Gardner, B.S., SC.D.—Power Transformer Department, General Electric Company, Pittsfield, Mass., U.S.A.

Frank S. Gardner gained his B.S. degree from the Massachusetts Institute of Technology in 1938 and the degree of Sc.D. in metallurgy three years later. On completing his postgraduate study he joined the American Brake Shoe Co., as a research metallurgist, working on the development of cast heat-resistant alloys, arc and induction melting, and creep and rupture testing. From 1945 to 1950 Dr. Gardner widened his experience working as a metallurgical engineer on product problems, then was appointed research metallurgist specializing in magnetic effects in steels. In 1954 he was appointed to his present position with General Electric Company as supervisor of an applied metallurgical research group.

Dr. Gardner is a member of the A.I.M.M.E. and A.S.M. and has been joint author of a number of technical research papers. His outside interests include community social relations, goals in education, swimming, and skiing.

F. S. Gardner

R. Linder

R. Linder—Research Metallurgist, Oxelösunds Järnverksaktiebolag, Oxelösund, Sweden. (*July issue.*)

Rolf Linder was born in Stockholm in 1927 and educated at Norra Real, Stockholm. He graduated in 1952 from the Royal Institute of Technology, Metallurgical Department, and then spent three years in research work on iron and steel metallurgy with Jernkontoret, Stockholm. In 1956 he took up his present position as research metallurgist at the new steelworks built by the Grängesberg Company at Oxelösund.

I. Ljungberg—Head of Development and Sales Division, Industrial Products, Husqvarna Vapenfabriks AB, Sweden.

Ivar Ljungberg was born at Stockholm in 1914 and received his basic technical education at HFTU, Stockholm. After working for four years with the Boliden Mining Company as an assistant analyst, he became a research engineer with this company in 1936. In 1939 he joined AB Separator as an engineer in the testing laboratory, returning to Boliden in 1941 as a research engineer. Mr. Ljungberg joined his present company in 1946 as a development engineer in the powder metallurgy division; he became assistant head of this division in 1951 and head in 1955. He took up his present post in 1956.

Ulf Notini—Director of Research, Jernkontoret, Sweden.

Mr. Notini graduated as metallurgist from the Royal Institute of Technology (KTH), Stockholm, in 1936 and for the next two years he was metallurgist at the physical laboratory of the Uddeholm Company, Hagfors Järnwerk. In 1938 he joined the Domnarfvets Järnwerk of Stora Kopparbergs Bergslags AB, as assistant to the Chief Metallurgist; he was later appointed Superintendent of the Fuel Combustion Department. He was appointed Production Manager in 1947, and in 1951 became Assistant General Manager in charge of development. Mr. Notini took up his present post at Jernkontoret in 1957.

A. C. Ogan, B.S.—Superintendent, Electric Furnaces, Duquesne Works, United States Steel Corporation.

Mr. Ogan was awarded his B.S. degree in 1931 at Rose Polytechnic Institute, Terre Haute, Indiana, and for the next two years he worked as Assistant to the Chief Chemist and Metallurgist at the Campbell Wyant

A. C. Ogan

and Cannon Foundry Co. in Michigan. Between 1936 and 1939 he gained extensive operating experience, first with vacuum furnaces at the South Works of the United States Steel Corporation in Chicago and then with electric-arc furnaces at the Northwestern Steel and Wire Co.

In 1939 Mr. Ogan returned to the United States Steel Corporation to work as a melter on high-frequency induction furnaces and electric-arc furnaces at the South Works, and in 1945 he was appointed Assistant Superintendent of the Electric Furnace Department at the Corporation's Duquesne Works. He has been Superintendent of this department since 1950.

Mr. Ogan is on the Furnace Committee of the A.I.M.M.E. and since 1953 he has been Secretary and Treasurer of the Electric Metal Makers Guild of the U.S.A. and Canada.

AFFILIATED LOCAL SOCIETIES

Ebbw Vale Metallurgical Society

The following officers and committee were elected for the 1958–1959 session at the Annual General Meeting on 8th May:

President
P. EDWARDS, A.I.I.A.

Vice-President
W. B. WILLIAMS, L.I.M.

Honorary Treasurer
I. GIDDINGS

Committee

J. J. BEESE
R. M. BETHEL
W. COOK, A.I.MECH.E
W. EDNY
A. W. ELLIS, A.M.I.E.E.
W. GOATMAN
L. G. HOBBS
D. J. JONES
T. JONES, A.C.I.S.
A. J. MEO
D. L. MILLS
J. T. MILLS
R. C. POWELL, B.SC.
F. E. PROBYN
J. F. SMITH
J. B. THICKINS, B.SC.

Honorary Joint Secretaries
W. E. WILLIAMS, L.I.M.
F. W. LEWIS

Staffordshire Iron and Steel Institute

The following officers and Council were elected for the 1958–1959 session at the Annual General Meeting on 22nd May:

President
W. H. B. WESSON, T.D.

Senior Vice President
L. W. LAW, M.A., M.I.E.E.

Junior Vice President
F. V. WRIGHT, M.I.MECH.E.

Trustees
P. JUMP, M.I.MECH.E.
H. E. COOKSON, T.D.
W. H. LEWIS, M.I.MECH.E.

Honorary Auditors
F. R. HARRIS
F. S. WOODWARD

Honorary Treasurer
G. E. LUNT

Members of Council

P. C. BROOKS
H. C. DAVIES, A.M.I.MECH.E.
W. K. V. GALE
E. B. GIBBONS
G. T. HAMPTON, F.I.M.
H. J. E. JONES, B.A.
M. R. LIDDIATT, A.I.M.
F. MEACHEM
W. S. WALKER, PH.D., M.SC.
L. HARPER

Members of Council (Past Presidents)

A. BIDDULPH, A.I.M.
K. H. WRIGHT, F.I.M.
K. G. LEWIS, M.SC., M.SC.(TECH)
G. PARKIN, A.MET., F.R.I.C., F.I.M.
A. W. SHORR, A.M.I.STRUCT.E.
E. MARKS, PH.D., M.SC.(TECH.)

Secretary
G. Riley

EDUCATION

Sheffield University—The Iron and Steel Institute Prize

The Iron and Steel Institute Prize for 1958 at Sheffield University has been awarded to Mr. **Peter Beardmore**, of Hanley, Stoke-on-Trent, who has graduated with first-class honours in metallurgy.

Courses at Kingston

Two special courses have been arranged by the Metallurgy Section of Kingston Technical College for the 1958–1959 Session.

A course of six lectures on the "Technology of Light Alloys" is being held on Thursday evenings at 7 p.m. starting on 11th November. The other course, also of six lectures, is concerned with "Metal Surface Treatment Techniques," and covers selected methods for the protection of metals against corrosion. This course is on Tuesday evenings at 7 p.m., beginning on 10th February.

Further details may be obtained from G. Isserlis, Engineering Department, Kingston Technical College, Fassett Road, Kingston-upon-Thames, Surrey.

Summer School on Non-Destructive Testing

As already noted (June issue, pp. 170–171), a Summer School on Non-Destructive Testing is being held at the Manchester College of Science and Technology from 8th to 12th September. The course is sponsored by the British National Committee for Non-Destructive Testing, of which The Iron and Steel Institute is a member. Details from the Registrar, The Manchester College of Science and Technology, Manchester 1.

BRITISH NUCLEAR ENERGY CONFERENCE

Membership

Members are reminded that The Iron and Steel Institute is a constituent body of the British Nuclear Energy Conference. This was originally formed in November, 1955, by The Institutions of Civil, Mechanical, Electrical, and Chemical Engineers and the Institute of Physics. Other Members are the Institutes of Metals and Fuel.

The B.N.E.C. enables any of the 120,000 Members of the constituent societies to attend all meetings in the field of nuclear energy arranged by them. The B.N.E.C. also itself arranges important symposia. The *Journal of the British Nuclear Energy Conference*, published quarterly since January, 1956, can be purchased by Members at the reduced rate of £1 10*s*. 0*d*. p.a. (published price £3 0*s*. 0*d*. p.a.).

[Further information may be obtained from the Secretary, B.N.E.C., The Institution of Civil Engineers, 1-7 Great George Street, London, S.W.1.]

NEWS OF SCIENCE AND INDUSTRY

Ironworks as Ancient Monuments

In its fourth annual report, published recently, the Ancient Monuments Board for England gives a list of "industrial monuments" that it feels are worthy of special protection. These include the Top Forge at Wortley Ironworks, Abraham Darby's blast-furnace at Coalbrookdale, and the bridge near Coalbrookdale,

which was the first cast-iron bridge in the world (1779). The Board states that the protection of industrial sites of historical interest is desirable in the light of " the growth of interest in economic, social and . . . technological history [which] is one of the characteristics of this age."

New Metallurgy Laboratories at Newcastle

Mr. Clive Cookson, Chairman of the Consett Iron Co., Ltd., performed the opening ceremony on 16th May for the extensions to the Metallurgy Department at King's College, University of Durham, Newcastle-upon-Tyne. The two new buildings, which are connected by a bridge at second-storey level, have a floor area of over 14,000 ft². They will permit the annual intake of students to be more than doubled, and will also increase the Department's facilities for research.

Sintering Symposium in Australia

The Port Pirie (South Australia) Branch of the Australasian Institute of Mining and Metallurgy is holding a symposium on sintering from 2nd to 6th September.

Industrial Publications Received

" Progress in Lubrication " is the title of a booklet published by Alexander Duckham and Co., Ltd. It records the company's activities in the past few years and outlines recent technological developments.

General Refractories Ltd., have published a brochure (Publication No. 111) on G.R. " Ferroclad " metal-cased chemically bonded basic bricks.

A leaflet (No. V26a) on standard gas-fired furnaces has been issued by The Incandescent Heat Company Ltd.; this replaces their earlier leaflet No. V26.

" The Cement for Industry " is the title of a 32-page booklet about Ciment Fondu issued by the Lafarge Aluminous Cement Co., Ltd.

" Automat Pig Iron " is described in an illustrated brochure from the Refined Iron Co. (Darwen) Ltd.

Leaflet No. V53 from The Incandescent Heat Co., Ltd., deals with the Incandescent–Laclede tile suspended arch.

A new adjustable swinging-arm ladle heater is the subject of a leaflet from the Monometer Manufacturing Co., Ltd.

Changes of Name and Address

Honeywell-Brown Ltd. is now known as Honeywell Controls Ltd., and has moved to new offices at Ruislip Road East, Greenford, Middlesex.

The Norwegian Ferrosilicon Producers Association has moved to Sørkedalsveien 6[II], P.O. Box 5199, Oslo (Telephone 60 45 90; telegrams FESIL OSLO).

The British Industrial Measuring and Control Apparatus Manufacturers Association (BIMCAM) is now at 9 Argyll Street, London, W.1. (REGENT 0568).

The Bibliothèque du Centre de Documentation du Centre National de la Recherche Scientifique is now at 15–17 quai Anatole-France, Paris 7e, France (INVALIDES 87–01, 83–84).

The general offices of Inland Steel Company have moved to Inland Steel Building, 30 West Monroe Street, Chicago 3, Ill., U.S.A. (FINANCIAL 6–0300).

DIARY

25th–29th Aug.—INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS (IUPAP)—Colloquium on Electronic Properties of Metals at Low Temperatures—Geneva, N.Y., U.S.A.

27th Aug.–3rd Sept.—BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE—Annual Meeting—Glasgow.

27th–31st Aug.—INSTITUTION OF PRODUCTION ENGINEERS—Annual Summer School—Ashorne Hill.

2nd–6th Sept.—AUSTRALASIAN INSTITUTE OF MINING AND METALLURGY (Port Pirie Branch)—Symposium on Sintering—Port Pirie, South Australia.

CO-OPERATIVE TRANSLATION SERVICE

The following translations are now available, in addition to those given on p. 272 of the July, 1958, issue of the Journal:

700. STEINHARDT and MÖHLER: " High Tensile Bolts for Steel Construction." *Berichte des Deutschen Ausschusses für Stahlbau*, 1954, No. 18. (£10 0*s*. 0*d*.)

745. ROGOZA: " Production of Sheets for Deep Drawing for the Motor Industry." *Stal*, 1957, Oct., pp. 941–943. (£2 10*s*. 0*d*.)

768. MÜLLER and LUEG: " Results of Testing the Operation of Blooming Mills. Part II—Forces encountered in the Rolling Process." *Stahl u. Eisen*, 1957, Oct. 31st, pp. 1583–1593. (£6 10*s*. 0*d*.)

800. KOCHENDÖRFER and ROHRBACH: " Indication of the Tendency to Brittle Fracture of Steels by Measurement of Yield Stress, Tearing Stress and Contraction on Fracture, on Tri-axially Stressed Specimens." *Arch. Eisenhüttenwesen*, 1955, Apr., pp. 213–227. (£9 0*s*. 0*d*.)

807. ŽIDEK and PEJČOCH: " Possibilities of Improving the Quality of Railway Tyres by Manufacture from Round Rolled Billets." *Hutnicke Listy*, 1956, No. 12, pp. 709–713. (£3 0*s*. 0*d*.)

824. KUWABARA *et al.*: " Practical Investigation on Work Rolls for Cold Rolling." *Tetsu to Hagané*, 1957, Jan., pp. 24–28. (£5 0*s*. 0*d*.)

832. FINKEL'SHTEIN and SHCHEGOL': " Increasing the Durability of Non-rotating Piercing Mill Plugs." *Stal*, 1957, Dec., pp. 1099–1103. (£3 10*s*. 0*d*.)

844. GOL'DENBERG: " Straightening Checkers of Air Regenerators in Open-hearth Furnaces." *Stal*, 1957, Dec., pp. 1094–1096. (£1 15*s*. 0*d*.)

881. STAHL: " Measuring Techniques for Controlling Electrical Installations in Steel Works and for Detecting Faults." *Stahl u. Eisen*, 1958, Jan. 23rd, pp. 94–100. (£4 10*s*. 0*d*.)

885. TULUEVSKY and KLIMENKO: " The Automatic Control of Open-hearth Heating Conditions at the Enakieve Iron and Steel Works." *Stal*, 1957, Dec., pp. 1086–1093. (£4 0*s*. 0*d*.)

886. IVANOV: " Regulation of Gas Flows by changing the Length and Cross-sections of Tuyeres." *Stal*, 1957, Dec., pp. 1071–1073. (£2 0*s*. 0*d*.)

890. BOHUS: " The Production of Hollow Boiler Shells from (100 ton) Hollow Ingots." *Hutnik*, 1956, No. 10, pp. 299–304. (£3 10*s*. 0*d*.)

897. IOFFE *et al.*: " The Influence of Technological Factors on the Electromagnetic Properties of Cold-rolled Transformer Steel." *Stal*, 1957, No. 10, pp. 936–940. (£2 10*s*. 0*d*.)

901. RICHTER *et al.*: " The (Basic) Hot-blast Cupola, Open-hearth Plant and L-D Converter, used as an Integrated Unit." *Stahl u. Eisen*, 1958, March 6th, pp. 273–284. (£8 10*s*. 0*d*.)

902. VOIGT: " The Basic Hot-blast Cupola Furnace in the Integrated Steelworks." *Stahl u. Eisen*, 1958, March 6th, pp. 284–291. (£5 15*s*. 0*d*.)

909. ALFEROVA *et al.*: " The Manufacture and Properties of Hot Rolled Tubes in Steel EI 595." *Stal*, 1958, Jan., pp. 60–66. (£5 0*s*. 0*d*.)

920. PAIDASSI: " The Oxidation of Iron Monoxide in Air in the Range 600–1350° C." *Acta Met.*, 1958, March, pp. 219–221. (£1 10*s*. 0*d*.)

921. PAIDASSI and LOPEZ: " Some Characteristics of the Oxidation of Magnetite in Air in the Range 400–1350° C." *Acta Met.*, 1958, March, pp. 221–223. (£1 10*s*. 0*d*.)

924. PAIDASSI: " The Kinetics of the Oxidation of Iron in Air in the Range 700–1250° C." *Acta Met.*, 1958, March, pp. 184–194. (£4 10*s*. 0*d*.)

930. WARROL and WAHLBERG: " Radiological Thickness Gauging in Hot Rolling." *Jernkontorets Ann.*, 1956, No. 12, pp. 907–929. (£6 0*s*. 0*d*.)

946. PALM and WARROL: " Comparison of the Advantages and Disadvantages of Turning and Grinding the Grooves in the Rolls of Wire Rod Mills." Part I—The Life of turned and ground Rolls. Part II—Economic Problems in the Dressing of Rolls. *Stahl u. Eisen*, 1958, Jan. 9th, pp. 35–37 and 37–39. (£3 15*s*. 0*d*.)

960. SCHINN: " Testing of Material and Work-pieces for Acceptance." *Stahl u. Eisen*, 1957, Nov. 14th, pp. 1675–1686. (£5 10*s*. 0*d*.)

967. DEINEKO: " Rolling Threads with Rolls of Different Diameters." *Stanki i Instrument*, 1957, No. 7, pp. 26–28. (£2 10*s*. 0*d*.)

969. TETERIN: " Geometrical Considerations in Oblique Rolling." *Stal*, Rolling and Tube Manufacture Supplement, 1958, pp. 243–258. (£5 0*s*. 0*d*.)

974. VOLKHAUSEN: " Cold Rolling Mills for Narrow- and Medium-Strip." *Blech*, 1957, Nov., pp. 88–92. (£4 0*s*. 0*d*.)

979. LAMBERT and MESSIN: " Application of the L-D Process to the Treatment of Phosphoric Irons." *Centre Doc. Sidér., Circ. d'Inform. Tech.*, 1958, No. 4, pp. 819–833. (£5 15*s*. 0*d*.)

983. REINHARDT: " The Behaviour of Basic Bricks in Reducing Atmosphere and their Behaviour as regards Carbon Monoxide Methane Disintegration." *Tonindustrie-Z.*, 1958, 3/4, pp. 38–41. (£3 0*s*. 0*d*.)

988. ANDONEV: " Experience in Designing and Operating Evaporative (Hot) Cooling of Metallurgical Furnaces." *Stal*, 1958, March, pp. 271–280. (£3 15*s*. 0*d*.)

ABSTRACTS OF CURRENT LITERATURE AND BOOK NOTICES

Iron and Steel Manufacture and Related Subjects

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*Abstracts, the reference to which is marked with an asterisk are, or are to be made available as translations.

MINERAL RESOURCES

A Theory of Exhalative-Sedimentary Ores. C. Oftedahl. (*Geol. Föreningens Förh*, 1958, **80**, Jan.-Feb., 1–19). [In English.] Iron formations are discussed.

Scandinavian Iron Ores and the Future of European Ore Supply. A. Bureau. (*Usine Nouv.*, 1957, **13**, Dec. 12, 25, 27, 29). A report of a conference. Estimates of supplies and requirements are presented and discussed.

The Soft Iron Ores of Vermlands Taberg. P. Ljunggren. (*Geol. Föreningens Förh.*, 1958, **80**, Jan.-Feb., 59–70). [In English.] Transformations are discussed on the evidence of X-ray and differential thermal analyses.

Manganese Deposits of Southwestern Oregon. R. N. Appling jun. (*U.S. Bur. Mines, Rep. Invest.*, 1958, No. 5369, Feb., pp. 56).

ORES—MINING AND TREATMENT

Studies of Economic Effectiveness of Iron-Ore Mining and Investment in Metallurgy. S. Kawinski. (*Prz. Techn.*, 1957, **78**, Oct., 732–736). [In Polish]. The importance of co-ordination of economic considerations with the technical problems are discussed. The author shows the economic advantages of the phosphorus process in the Polish iron and steel industry.

Mining in Scandinavia. III. Operations in South-Central Sweden. C. Mamen. (*Can. Min. J.*, 1958, **79**, Mar., 71–78). The Grängesberg mine of the T.G.O. organization, the Stora-Kopparberg mine at Falun and the Bodås Mine of the Sandviken Steel Works are described.

Flotation. N. Arbiter. (*Ind. Eng. Chem.*, 1958, **50**, March, Part 2, 442–446). A review for 1957. (142 refs.).

The Use of Mixed Collectors in the Flotation Process. A. Molicka-Haniswetz. (*Prace Inst. Ministerstwa Hutnictwa*, 1957, **9**, (3), 136–140). [In Polish]. The use of mixed collectors in the flotation process instead of the usual single collectors has led to an increase in enriched mineral recovery. Experiments were conducted with zinc-lead, copper and iron ores.

The Basis of the Intensification of the New Technology for the Treatment of Complex Polymetallic Iron Ores. D. A. Bogatskii and G. G. Urazov. (*Izvest. Akad. Nauk Otdel. Khimi.*, 1957 (8), 898–908). A method is described, applicable industrially, for enriching ores by direct reduction and subsequent chloridizing calcination to transform the metals into easily-soluble chlorides. This method of chemical enrichment by heating renders possible the utilization of difficult silicate ores economically unusable up to now.—L. H.

The Extraction of Cobalt and Nickel from Complex Iron Ores. M. Pedlík. (*Hutn. Listy*, 1958, **13**, (1), 89–96). [In Czech.]. A method of extracting Ni and Co from iron ores containing only about 1% Ni is described. Ni and Co are extracted by means of an ammonia-lye solution; the remaining waste sludge is used in the blast-furnace. Further processing of the extract is discussed. The cost of extracting lean ores of this type is higher than the extraction of high-quality ores, but the difference is markedly reduced through the possibility of by-product utilization.—P. F.

A Study on the Utilization of Jarosite. On the Recovery of K_2SO_4. Y. Kanamori. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1019–1021). Results are given of calcining tests on this ore (containing 33% Fe and 7·5% K_2O), which show good recovery figures for K_2SO_4, up to 97% with −10 mesh material.—K. E. J.

Tests Regarding the Compacting of Brown Iron Ore from the Lahn Region and Other German Iron Ores, in a Vacuum Extrusion Press. H. Häuser. (*Z. Erz. Met.*, 1957, **10**, Sept., 443–450). The author describes the installation used in the beneficiation of certain iron ores by means of a vacuum press. The process is said to be successful but uneconomic because of lack of a cheap source of heat nearby.—R. P.

On the Magnetising Roasting of Low-grade Iron Ores by a Flow-Solid Roaster. M. Tanaka. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 876–878). [In Japanese]. Experimental details are given for fluidized-bed roasting of Kanahada and Tohira ores of various sizes. As roasting temperatures increased between 500° and 650° C, the iron recovery (which varied between 65 and 82%) improved by approx. 18%.—K. E. J.

Fluidisation Methods of Ore Roasting. F. Kadlec. (*Hutník*, 1958, **8**, (1), 22–26). [In Czech]. Examples of the scope of fluidization in metallurgical processes are given and discussed. By means of ore fluidization volatile metals such as Zn, Sn, Pb, Sb, As and sulphur may be removed or extracted; Cu, Zn, Co and Fe may be prepared for processing or enriching. Fluidization may be suitable in special cases in which it has hitherto not been tried, or it may lead to economics if used to replace existing less efficient methods.—P. F.

Reduction of Pyrites Cinder and Iron Ore in a Fluidized Bed. T. Koizumi. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1018–1019). Results are given for the fluidized reduction of pyrites cinder by CO, in terms of Fe_2O_3, Fe_3O_4, FeO and metallic iron formed at various temperatures after various times. Amounts of metallic iron exceeding 80% are formed after treatment at 900° C for 90 min.—K. E. J.

Sintering Test of Iron Ores by a Small Greenawalt-type Sintering Machine. III. Sintering Test with Lime Addition. N. Nishida. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 878–880). [In Japanese]. Details are given of variation of suction with moisture content, and of suction and waste-gas temp. with sintering time. As additives [lime, limestone and Ca $(OH)_2$] were increased from 0 to 8%, the sintering time fell to a minimum of approx. 13 min at approx. 5% of additive, and the maximum of strength occurred at about the same figure.—K. E. J.

Sintering Test of Iron Ore Mixed with Green Pellets. T. Saito. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 880–882). [In Japanese]. The effects of pellet proportions (up to 30%) and moisture (9–13%) on sintering time are investigated. A minimum of sintering time is found with 15% of pellets in the mix. Permeability of the materials increases with the proportion of pellets, but the sintering permeability is at a maximum with 5% of pellets.—K. E. J.

Sintering Test of Open-Hearth Slag and Scale. K. Miyakawa. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 882–884). Results are given for sintering at high and low suction with slag additions; these include FeO content, strength, yield/sintering time ratio, yield and sintering time for coke contents of 3, 4 and 5%. Sintering time tends to fall, and strength and yield to rise, with additions rising to 10%. Results for scale additions show increases in strength with additions up to 10%, and to higher figures in some cases.—K. E. J.

Study on the Manufacture of Excellent Sinter by Magnetising Roasting of Limonite.

III. Pilot Plant Test. T. Ikeno. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 884–886). [In Japanese]. The results given include data on magnetizing and arsenic removal rates by roasting and by sintering, and sintering operations.—K. E. J.

The Addition of Pulverised Calcitic Limestone to Magnetite Concentrates and Its Beneficial Effects on Improved Sinter Quality and Increased Blast Furnace Production. R. K. Glass. (*Blast. Fur. Steel Plant*, 1958, **46**, Feb., 198–204). The development, production and properties of "Chateaugay sinter" is described. Reducibility is shown to be improved and greater thermal efficiency in the blast furnace was obtained.

Pelletising Finely Pulverised Iron Ores. G. V. Gubin. (**Metallurg*, 1958, (2), 3–4). For pelletising fine ores it was found that disc granulators are easier to control as regards speed, angle of inclination and dimensions of pellets. When pellets are roasted at 1100 to 1200° C, a slag is formed from iron oxide and silica which retards further oxidation of the magnetite grains.

It is preferable to roast pellets on sinter strands rather than in shaft furnaces. Sinter plants with combined top and bottom draught eliminate the harmful effect of condensation of moisture on the strength of the pellets in the bottom layers of the bed and enable the thickness of the bed of pellets for roasting to be increased to 3 ft.

A Russian catalytic method of pelletizing including roasting is described. Coke breeze and brown coal semi-coke are used as reducing agents. Softening temperature of the pellets is 1200–1300° C. Such concentrates are widely used in electric furnaces, low shaft blast furnaces and furnaces based on fluidization techniques.—B. S.

Initial Sintering of Alumina and Haematite. R. L. Coble. (*J. Am. Ceram. Soc.*, 1958, **41**, Feb., 55–62). Pressed compacts were examined and the mechanism of sintering and shrinkage noted and diffusion coefficients were calculated. The activation energy of neck growth was measured as 165 Kcal/mole.

How Theory Can Help Make More Sinter. E. W. Voice and R. Wild. (*J. Met.*, 1958, **10**, Feb., 105–110). A review of the work of BISRA is presented, and results are discussed and related to plant problems. Fuel requirements were found to depend upon heat requirements and air requirements to depend more upon the heat capacity of the sinter mix than on the oxygen demand of the fuel. In sintering a series of fronts travel down the bed and the efficiency of the process depends upon these reaction fronts being properly in phase with one another.

Updraft Pelletizing of Specular-Hematite Concentrates. D. C. Violetta. (*J. Met.*, 1958, **10**, Feb., 118–121; *Min. Eng.*, 1958, **10**, Mar., 354–356). The advantages of the system and the development of furnaces, laboratory tests of the process and the initiation of plant-scale operation are surveyed.

Downdraft Taconite Pellet Hardening. A. English and M. F. Morgan. (*J. Met.*, 1958, **10**, Feb., 122–124; *Min. Eng.*, 1958, **10**, Mar., 357–359). Development on a laboratory and pilot-plant scale of a continuous grate furnace and the building of a 3,750,000-t per year installation are briefly described.

The Lurgi Pelletizing Process: A Combined Updraft-Downdraft Technique. K. J. E. Meyer and H. Rausch. (*J. Met.*, 1958, **10**, Feb., 129–133; *Min. Eng.*, 1958, **10**, Mar., 359–360). The production of the green pellets, drying, hardening and cooling are described and the special features of the process are summarized.

Pelletizing in Shaft Furnaces. F. D. De Vaney. (*J. Met.*, 1958, **10**, Feb., 125–128; *Min. Eng.*, 1958, **10**, Mar., 361–364). An experimental plant using fine ores is described and operating results are given.

FUEL, PREPARATION, PROPERTIES AND USES

From Coal to Coke. R. Cheradame. (*B.C.U.R.A. Quart. Gaz.*, 1957, (33), 1–12). A lecture. Aspects of the carbonization process are reviewed.

Conversion of a Non-Coking Coal into Coking Type by Partial Hydrogenation. L. D. Ahuja, J. N. Sharma, K. A. Kini and A. Lahiri. (*J. Sci. Ind. Res.*, 1958, **17A**, Jan., 27–29). The process was carried out at 200 atm. and 375° or at 30 atm. with a catalyst solution impregnation.

On the Manufacture of Shaped Metallurgical Coke from Inferior Coal. IV. S. Ida. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1024–1026). Details are given of the properties of cokes made from blends of low-grade coal briquetted with special binders.—K. E. J.

Evaluation of Coke Quality by a Compressive Test. D. E. Krause and E. A. Lange. (*Trans. A.F.S.*, 1956, **64**, 209–213).

Sampling of Coke Carried by Board Barges. H. Ihara. (*Tetsu-to-Hagane*, 1957, **43**, 1023–1024). Data are given for moisture variations in coke under various climatic conditions.—K. E. J.

AIR POLLUTION AND SMOKE

Air and Water Pollution in the Iron and Steel Industry. A. Parker. (*J.I.S.I.*, 1958, August, 297–302). (This issue).

Giant Fume Catcher Stops Fluoride Emission. (*Chem. Eng.*, 1958, **65**, Feb. 24, 66, 68). A cyclone precipitator has been installed at U.S. Steel Corp. Columbia-Geneva Mill, Utah.

Dispersal of Dust Particles from Elevated Sources. II. Limitations of the Approximate Theory. G. T. Csanady. (*Aust. J. Phys.*, 1957, **10**, Dec., 558–564).

Equipment for Cupola-Emission Control. J. M. Kane. (*Trans. A.F.S.*, 1956, **64**, 525–531). Cinders, dust, smoke and fumes are considered and wet and dry methods of collection, electrostatic precipitators and fabric collectors are reviewed.

Air and Water Pollution in the Iron and Steel Industry. (*I.S.I. Special Report No.* 61; *of a Meeting*, 11–12*th Dec.*, 1957 *in London*, 1958, pp. 260). **External Pollution from an Iron and Steelworks and Measures Towards its Reduction.** S. H. Brooks and W. J. Calvert. (5–15). Appleby-Frodingham practice is described. (17 References). **External Dust Deposition and Sulphur Emission.** H. G. Jones and J. T. Davies. (16–22). **The Capital Costs of Some Waste-Gas Cleaning Plant for Use in Iron and Steelworks.** R. A. Granville. (23–30). Data, mostly relating to electro-precipitators are given from a questionnaire. **Mitigation of Air Pollution in Sinter Plants.** A. H. Meadley, J. G. Colvin and H. J. Camble. (39–48). Work at Corby is reported. **Mitigation of Smoke, Dust and Grit at Coke Oven Plants.** G. W. Lee and J. P. Graham. (51–55). **The Extraction of Sulphur from Coke-Oven Gas and the Manufacture of Sulphuric Acid.** P. R. Purcell and T. H. Williams. (56–61). The Collin ammonia process of extraction and the Chimiebau wet-contact acid process as used at Corby are described. **Operation of Electrostatic Precipitators on Open-Hearth Furnaces at Fairless Works.** E. B. Speer. (67–73). Use on 330-t basic O.H. furnaces is surveyed. Construction, factors in design, control and performance are considered. **A Pilot Plant for the Removal of Iron-oxide Dust from the Fumes arising in the Pre-refining of Iron with Oxygen.** L. G. Septier. (74–81). The plant at Mondeville works, Soc. Métallurgique de Normandie, with a dry and a wet cleaner in series, which removes $> 99\%$ of the red fumes formed in O_2 blowing is described. **Waste Gas Cleaning Systems at Oxygen Steel Plants.** A. Vacek and A. Schertler. (82–89). **Gas Cleaning in Relation to Oxygen Pre-refining and the Rotor Process at Oberhausen.** A. Behrendt. (90–96). **Dynamic Dust and Fume Precipitators.** F. Wright. (103–107). The Rotoclone is considered, with a discussion of principles and selection. **Cleaning of Fume from Arc Furnaces.** A. S. Hipkin. (108–114). The requirements of the Clean Air Act are outlined and existing practice is reviewed. **Measurement of Dust in Flue Gases.** R. Jackson and R. A. Granville. (119–128). Trials at sinter plants and O.H. furnaces of sampling direct from gases, and the difficulties encountered with producer-gas cleaners are described. **The Complete Elimination of Dust from Gases at 300–400° C.** H. L. Riley. (129–131). A glass-fibre filter is described and its possible uses are noted. **The Fulham-Simon-Carves Process for the Recovery of Sulphur from Flue Gases.** T. Kennaway. (132–142). **General Technical Aspects of Pollution of Rivers.** B. A. Southgate. (153–156). Effects on sources of water, fisheries and oxygen content and conditions in estuaries are briefly surveyed. **The Treatment of Effluent from Blast-Furnace Gas-Cleaning Plant.** F. W. Edwards and C. J. Smith. (163–170). **The Extent of Water Pollution in an Iron and Steel Works and Steps Taken Towards its Prevention.** G. W. Cook. (177–186). Problems at Appleby-Frodingham are reviewed. General effluent and coke-oven, rolling mill and pickle effluents are considered. **Sewage Effluent as Industrial Water.** C. W. Shingledecker. (187–191). Experience at Bethlehem Steel is outlined in drawing sewage disposal effluent from Baltimore. **Methods of Approach to Coke-Oven Effluent Problems.** R. G. Cooper. (197–202). Legal considerations are reviewed. **Effluent Purification at the Avenue Carbonization and Chemical Plant of the National Coal Board.** E. I. Akeroyd and G. W. J. Bradley. (203–206). **The Biological Treatment of Coke-Oven Effluents.** N. M. Potter and J. W. Hunt. (207–218). **The Treatment and Disposal of Effluents in the Gas and Coke Industries.** J. R. Catchpole. (219–225). **The B.I.G.R.A. Autoxidation Process for Acid Pickle Liquors.** W. Bullough. (239–244). Catalytic oxidation of SO_2 in $MnSO_4$ solution is described. **Neutralization of Spent Pickle Liquor.** R. D. Hoak. (248–253). Factors in reducing costs of neutralization are discussed.

TEMPERATURE MEASUREMENT AND CONTROL

Immersion Pyrometry in Steelmaking Furnaces. J. Říha and J. Skála. (*Slévárenství*, 1958, **6**, (1), 5–11). [In Czech]. The development and application of immersion pyrometry and some results of operational research based on immersion pyrometry studies are considered. These showed (*a*) that it was desirable to determine the bath temperature before starting deoxidation in the O.H. furnace, and also prior to tapping, (*b*) that it facilitated the determination of optimum casting temperatures for various types of steel used in the foundry, and (*c*) it indicated that in the electric furnace one temperature determination was sufficient, i.e. during the reduction period.—P. F.

The Venturi Pneumatic Pyrometer. A. M. Godridge, R. Jackson and G. G. Thurlow. (*J. Sci. Inst.*, 1958, **35**, Mar., 81–88). Use in the downtakes of O.H. furnaces is described and its superiority to the suction pyrometer is claimed.

An Experimental Core Series Designed for Use in Pottery Decorating Kilns and Enamelling Furnaces. L. E. Shipley. (*Amer. Ceram. Soc. Bull.*, 1958, **37**, Jan., 9–11). The series extends from 520–1000° C at 10° intervals.

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BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG-IRON

Some 25,000 Hours' Operating Experience with Blast Furnace Sets. A. Jaumotte. (*Oil Eng. Gas Turb.*, 1958, **25**, Mid March, 429–432). An account of the gas turbine installation at Société Métallurgique Hainaut-Sambre, Couillet, and its operation.

The Broken Hill Proprietary Co. Ltd., Newcastle Works. (*Blast Fur. Steel Plant*, 1958, **46**, Feb., 169–197). An account of all departments is given.

On the Wall Corrosion of the Blast Furnace. N. Nakamura. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1026–1028). Physical properties and analyses are listed for several samples of brick from the stack and hearth before blowing-in and after blowing-out, together with a diagram of the lining of the furnace wich was badly corroded. Glass, kaliophilite and zincite were found in areas of attack.—K. E. J.

Experience with Sinter Burden in Swedish Blast-furnaces. Ulf Notini. (*J.I.S.I.*, 1958, August, 322–326). [This issue].

Blast-Furnace Operation with a Top-Gas Analysis Meter. K. Yasuda. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 943–945). Variations in the CO_2 content of the top gas are examined for conditions of slipping, checking and hanging; the CO_2 contents are also compared with variations in the S and Si contents in the iron when the furnace is in poor condition or recovering.—K. E. J.

PROPERTIES, TREATMENT AND USE OF SLAGS

Modern Ideas on the Constitution of Molten Slags and the Thermodynamic Activities of Their Constituents. M. Rey. (*Centre d'Études Sidérur.*, 1954, pp. 94). Chemical aspects of structure, affinity for oxygen, and the molecular interpretation of chemical reactions in slags and the ionic interpretations are discussed. Methods of measurement of thermodynamic quantities and their phase diagrams and the relation between them and to structure are described with illustrations from binary and ternary systems. **Viscosity and Structure of Liquid Slags.** P. Kozakevitch and G. Urbain. (pp. 111). Theory, X-ray data, transport numbers and values for viscosity are discussed and the systems CaO–MgO–Al_2O_3–SiO_2, CaO–Al_2O_3–SiO_2, CaO–MgO–Al_2O_3–SiO_2, CaO–FeO–MnO–SiO_2 and the ternaries, the effects of TiO_2 and Cr_2O_3, and the CaO–FeO–P_2O_5–SiO_2 system are reviewed. Methods of viscosity measurement are then described and, in a supplement, the effects of Al_2O_3 on blast furnace and steel furnace slags are considered.

Phase Equilibria at High Temperatures in Iron Silicate Systems. A. Muan. (*Amer. Ceram. Soc. Bull.*, 1958, Feb., 81–84). Effects of O_2 in the gas phase are worked out. The Fe–O, FeO–Fe_2O_3–SiO_2 systems are shown.

Reactions between Molten Slags Containing TiO_2 and Pig Iron. R. Sato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 928–930). Inter-relationships are shown between CaO/SiO_2 ratio, TiO_2 in the slag and Si and S in the metal for electric furnace smelting; and between the CaO/SiO_2 ratio, FeO in the slag, and Si and S in the metal for blast-furnace smelting.—K. E. J.

Structural Interpretation of Immiscibility in Oxide Systems: III. Effect of Alkalis and Alumina in Ternary Systems. E. M. Levin and S. Block. (*J. Am. Ceram. Soc.*, 1958, **41**, Feb., 49–54). The effects of homogenizers are explained on various postulates. B does not act as a homogenizer. Two methods for determining the amount required for complete miscibility are given.

Study of the Properties of Hydrogen Dissolved in Liquid Slag by the E.M.F. Method. L. N. Barmin, O. A. Esin and S. K. Chuchmarev. (*Izvest. Akad. Nauk, Otdel. Tekhn.*, 1957, (9), 114–118). [In Russian]. In the investigation described, the behaviour of a hydrogen electrode in slags was studied, two types of oxygen electrode (gaseous and magnesia) being compared. Most experiments were with CaO–Al_2O_3–SiO_2–MgO slags (mol. fractions 0·34–0·64, 0·07–0·29, 0·06–0·59, 0–0·08, respectively). A reversible hydrogen electrode could be realized comparatively easily in the absence of easily reducible oxides, and magnesia in contact with the liquid slag functioned as an oxygen electrode. The experiments showed that the activity of water in slag is proportional to the square root of the activity of the lime, suggesting that hydrogen in slag exists in the form of hydroxyl anions. The authors suggest that from the e.m.f. of a hydrogen-oxygen cell with fused slag the basicity of the latter can be found.—S. E.

On Basicity and Potential of Slag. K. Sawamura. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 948–949).—K. E. J.

Microstructure of Slags Containing TiO_2. I. Microstructure of the Slag System CaO-TiO_2-SiO_2. II. Effect of Al_2O_3 and MgO on Microstructure of Slags. R. Sato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 869–870; 870–872). I. An equilibrium diagram showing the important parts of the CaO–TiO_2 system is given. II. Structural diagrams are given, to show the compounds formed in the CaO–TiO_2–SiO_2–Al_2O_3 and CaO–TiO_2–SiO_2–MgO systems.—K. E. J.

PRODUCTION OF STEEL

Metal Scrap Disposal. J. Wojtyna and Z. Mikolajczyk. (*Prz. Techn.*, 1956, **77**, Dec., 542–546). [In Polish]. The author emphasizes the importance of utilizing metal scrap for the Polish Iron and Steel Industry and discusses different technical and economic problems connected with it.

Report of the Heat Economy Sub-division of the Co-operative Society for Research into Iron and Steel Techniques. I. (*Tetsu-to-Hagane*, 1957, **43**, Oct., 1159–1166). [In Japanese].

Oxygen in Steelmaking. J. A. Charles. (*Research*, 1958, **11**, Mar., 102–107). A general review.

Some Patterns of Gas-Mixing in Metallurgical Furnaces. E. E. Sjöstrand. (*Jernkont. Ann.*, 1958, **142**, (1), 15–33). A review of published research ducing the last 20 years. The basic work by Rummel et al., theory and experiments, new methods of studying flow of gases, and some practical results are given.

Product Quality—Keynote of Drive Systems Engineering. E. H. Browning and L. F. Stringer. (*Iron Steel Eng.*, 1957, **34**, Dec., 114–122). This paper discusses the new emphasis on quality production in the American steel industry and describes a number of new developments which are essentially geared to produce higher grade steels—generally these developments are in control mechanisms and the authors describe electric arc furnace regulating systems, card programmed automatic screw-down control for reversing mills, hot and cold strip mill and rod mill control and electrolytic tinning line control.—M. D. J. B.

Experience in Using LP-gas in the Steel Works. D. Yoshinari. (*Tetsu-to-Hagane*, 1957, **43**, 1021–1023). Some physical properties of LP gases (propane, but-1-ene, butane and homologues) are listed and details are given of supply systems for butane gas.

Flame Radiation in a Furnace. T. Shirasawa. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 963–965). An experimental instrumented oil-burning furnace is described. Analyses are given for three types of heavy oil used. The effects on emissivity and temperature of variation in the atomizing medium and pressure, in the quantity of fuel and in the type of fuel are shown graphically.—K. E. J.

III. Pilot Plant Test. T. Ikeno. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 884–886). [In Japanese]. The results given include data on magnetizing and arsenic removal rates by roasting and by sintering, and sintering operations.—K. E. J.

The Addition of Pulverised Calcitic Limestone to Magnetite Concentrates and Its Beneficial Effects on Improved Sinter Quality and Increased Blast Furnace Production. R. K. Glass. (*Blast. Fur. Steel Plant*, 1958, **46**, Feb., 198–204). The development, production and properties of "Chateaugay sinter" is described. Reducibility is shown to be improved and greater thermal efficiency in the blast furnace was obtained.

Pelletising Finely Pulverised Iron Ores. G. V. Gubin. (*Metallurg*, 1958, (2), 3–4). For pelletising fine ores it was found that disc granulators are easier to control as regards speed, angle of inclination and dimensions of pellets. When pellets are roasted at 1100 to 1200° C, a slag is formed from iron oxide and silica which retards further oxidation of the magnetite grains.

It is preferable to roast pellets on sinter strands rather than in shaft furnaces. Sinter plants with combined top and bottom draught eliminate the harmful effect of condensation of moisture on the strength of the pellets in the bottom layers of the bed and enable the thickness of the bed of pellets for roasting to be increased to 3 ft.

A Russian catalytic method of pelletizing including roasting is described. Coke breeze and brown coal semi-coke are used as reducing agents. Softening temperature of the pellets is 1200–1300° C. Such concentrates are widely used in electric furnaces, low shaft blast furnaces and furnaces based on fluidization techniques.—R. S.

Initial Sintering of Alumina and Haematite. R. L. Coble. (*J. Am. Ceram. Soc.*, 1958, **41**, Feb., 55–62). Pressed compacts were examined and the mechanism of sintering and shrinkage noted and diffusion coefficients were calculated. The activation energy of neck growth was measured as 165 Kcal/mole.

How Theory Can Help Make More Sinter. E. W. Voice and R. Wild. (*J. Met.*, 1958, **10**, Feb., 105–110). A review of the work of BISRA is presented, and results are discussed and related to plant problems. Fuel requirements were found to depend upon heat requirements and air requirements to depend more upon the heat capacity of the sinter mix than on the oxygen demand of the fuel. In sintering a series of fronts travel down the bed and the efficiency of the process depends upon these reaction fronts being properly in phase with one another.

Updraft Pelletising of Specular-Hematite Concentrates. D. C. Violetta. (*J. Met.*, 1958, **10**, Feb., 118–121; *Min. Eng.*, 1958, **10**, Mar., 354–356). The advantages of the system and the development of furnaces, laboratory tests of the process and the initiation of plant-scale operation are surveyed.

Downdraft Taconite Pellet Hardening. A. English and M. F. Morgan. (*J. Met.*, 1958, **10**, Feb., 122–124; *Min. Eng.*, 1958, **10**, Mar., 357–359). Development on a laboratory and pilot-plant scale of a continuous grate furnace and the building of a 3,750,000-t per year installation are briefly described.

The Lurgi Pelletizing Process: A Combined Updraft-Downdraft Technique. K. J. E. Meyer and H. Rausch. (*J. Met.*, 1958, **10**, Feb., 129–133; *Min. Eng.*, 1958, **10**, Mar., 359–360). The production of the green pellets, drying, hardening and cooling are described and the special features of the process are summarized.

Pelletizing in Shaft Furnaces. F. D. De Vaney. (*J. Met.*, 1958, **10**, Feb., 125–128; *Min. Eng.*, 1958, **10**, Mar., 361–364). An experimental plant using fine ores is described and operating results are given.

FUEL, PREPARATION, PROPERTIES AND USES

From Coal to Coke. R. Cheradame. (*B.C.U.R.A. Quart. Gaz.*, 1957, (33), 1–12). A lecture. Aspects of the carbonization process are reviewed.

Conversion of a Non-Coking Coal into Coking Type by Partial Hydrogenation. L. D. Ahuja, J. N. Sharma, K. A. Kini and A. Lahiri. (*J. Sci. Ind. Res.*, 1958, **17A**, Jan., 27–29). The process was carried out at 200 atm. and 375° or at 30 atm. with a catalyst solution impregnation.

On the Manufacture of Shaped Metallurgical Coke from Inferior Coal. IV. S. Ida. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1024–1026). Details are given of the properties of cokes made from blends of low-grade coal briquetted with special binders.—K. E. J.

Evaluation of Coke Quality by a Compressive Test. D. E. Krause and E. A. Lange. (*Trans. A.F.S.*, 1956, **64**, 209–213).

Sampling of Coke Carried by Board Barges. H. Ihars. (*Tetsu-to-Hagane*, 1957, **43**, 1023–1024). Data are given for moisture variations in coke under various climatic conditions.—K. E. J.

AIR POLLUTION AND SMOKE

Air and Water Pollution in the Iron and Steel Industry. A. Parker. (*J.I.S.I.*, 1958, August, 297–302). (This issue).

Giant Fume Catcher Stops Fluoride Emission. (*Chem. Eng.*, 1958, **65**, Feb. 24, 66, 68). A cyclone precipitator has been installed at U.S. Steel Corp. Columbia-Geneva Mill, Utah.

Dispersal of Dust Particles from Elevated Sources. II. Limitations of the Approximate Theory. G. T. Csanady. (*Aust. J. Phys.*, 1957, **10**, Dec., 558–564).

Equipment for Cupola-Emission Control. J. M. Kane. (*Trans. A.F.S.*, 1956, **64**, 525–531). Cinders, dust, smoke and fumes are considered and wet and dry methods of collection, electrostatic precipitators and fabric collectors are reviewed.

Air and Water Pollution in the Iron and Steel Industry. (*I.S.I. Special Report No.* 61; *of a Meeting*, 11–12*th Dec.*, 1957 *in London*, 1958, pp. 260). **External Pollution from an Iron and Steelworks and Measures Towards its Reduction.** S. H. Brooks and W. J. Calvert. (5–15). Appleby-Frodingham practice is described. (17 References). **External Dust Deposition and Sulphur Emission.** H. G. Jones and J. T. Davies. (16–22). **The Capital Costs of Some Waste-Gas Cleaning Plant for Use in Iron and Steelworks.** R. A. Granville. (23–30). Data, mostly relating to electroprecipitators are given from a questionnaire. **Mitigation of Air Pollution in Sinter Plants.** A. H. Meadley, J. G. Colvin and H. J. Camble. (39–48). Work at Corby is reported. **Mitigation of Smoke, Dust and Grit at Coke Oven Plants.** G. W. Lee and J. P. Graham. (51–55). **The Extraction of Sulphur from Coke-Oven Gas and the Manufacture of Sulphuric Acid.** P. R. Purcell and T. H. Williams. (56–61). The Collin ammonia process of extraction and the Chimiebau wet-contact acid process as used at Corby are described. **Operation of Electrostatic Precipitators on Open-Hearth Furnaces at Fairless Works.** E. B. Speer. (67–73). Use on 330-t basic O.H. furnaces is surveyed. Construction, factors in design, control and performance are considered. **A Pilot Plant for the Removal of Iron-oxide Dust from the Fumes arising in the Pre-refining of Iron with Oxygen.** L. G. Septier. (74–81). The plant at Mondeville works, Soc. Métallurgique de Normandie, with a dry and a wet cleaner in series, which removes > 99% of the red fumes formed in O_2 blowing is described. **Waste Gas Cleaning Systems at Oxygen Steel Plants.** A. Vacek and A. Schertler. (82–89). **Gas Cleaning in Relation to Oxygen Pre-refining and the Rotor Process at Oberhausen.** A. Behrendt. (90–96). **Dynamic Dust and Fume Precipitators.** F. Wright. (103–107). The Rotoclone is considered, with a discussion of principles and selection. **Cleaning of Fume from Arc Furnaces.** A. S. Hipkin. (108–114). The requirements of the Clean Air Act are outlined and existing practice is reviewed. **Measurement of Dust in Flue Gases.** R. Jackson and R. A. Granville. (119–128). Trials at sinter plants and O.H. furnaces of sampling direct from gases, and the difficulties encountered with producer-gas cleaners are described. **The Complete Elimination of Dust from Gases at 300–400° C.** H. L. Riley. (129–131). A glass-fibre filter is described and its possible uses are noted. **The Fulham-Simon-Carves Process for the Recovery of Sulphur from Flue Gases.** T. Kennaway. (132–142). **General Technical Aspects of Pollution of Rivers.** B. A. Southgate. (153–156). Effects on sources of water, fisheries and oxygen content and conditions in estuaries are briefly surveyed. **The Treatment of Effluent from Blast-Furnace Gas-Cleaning Plant.** F. W. Edwards and C. J. Smith. (163–170). **The Extent of Water Pollution in an Iron and Steel Works and Steps Taken Towards its Prevention.** G. W. Cook. (177–186). Problems at Appleby-Frodingham are reviewed. General effluent and coke-oven, rolling mill and pickle effluents are considered. **Sewage Effluent as Industrial Water.** C. W. Shingledecker. (187–191). Experience at Bethlehem Steel is outlined in drawing sewage disposal effluent from Baltimore. **Methods of Approach to Coke-Oven Effluent Problems.** R. G. Cooper. (197–202). Legal considerations are reviewed. **Effluent Purification at the Avenue Carbonisation and Chemical Plant of the National Coal Board.** E. I. Akeroyd and G. W. J. Bradley. (203–206). **The Biological Treatment of Coke-Oven Effluents.** N. M. Potter and J. W. Hunt. (207–218). **The Treatment and Disposal of Effluents in the Gas and Coke Industries.** J. R. Catchpole. (219–225). **The B.I.S.R.A. Autoxidation Process for Acid Pickle Liquors.** W. Bullough. (239–244). Catalytic oxidation of SO_2 in $MnSO_4$ solution is described. **Neutralisation of Spent Pickle Liquor.** R. D. Hoak. (248–253). Factors in reducing costs of neutralization are discussed.

TEMPERATURE MEASUREMENT AND CONTROL

Immersion Pyrometry in Steelmaking Furnaces. J. Říha and J. Skála. (*Slévárenství*, 1958, **6**, (1), 5–11). [In Czech]. The development and application of immersion pyrometry in the V. I. Lenin Steelworks in Pilsen is described and some results of operational research based on immersion pyrometry studies are considered. These showed (*a*) that it was desirable to determine the bath temperature before starting deoxidation in the O.H. furnace, and also prior to tapping, (*b*) that it facilitated the determination of optimum casting temperatures for various types of steel used in the foundry, and (*c*) it indicated that in the electric furnace one temperature determination was sufficient, i.e. during the reduction period.—F. F.

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The Treatment of Water-Borne Wastes from Steel Plants. R. Nebolsine. (*Iron Steel Eng.*, 1957, **34**, Dec., 125–150). The author describes the treatment of waste products with particular emphasis on steel plant problems. Costs are given. The waste products discussed are: flue dust, mill scale and free oils, soluble oils, waste pickle liquor, phenols and cinder.—M. D. J. B.

Trade Effluent and Water Supplies in Western Germany. (*Federation of British Industries report*, 1957, Nov., pp. 64). A report of a tour. The iron works at Muelheim/Rhur and the steel works of the Bochumer Verein were visited as well as chemical works, a paper mill and river and sewage works.

BLAST-FURNACE PRACTICE AND PRODUCTION OF PIG-IRON

Some 25,000 Hours' Operating Experience with Blast Furnace Sets. A. Jaumotte. (*Oil Eng. Gas Turb.*, 1958, **25**, Mid March, 429–432). An account of the gas turbine installation at Société Métallurgique Hainaut-Sambre, Couillet, and its operation.

The Broken Hill Proprietary Co. Ltd., Newcastle Works. (*Blast Fur. Steel Plant*, 1958, **46**, Feb., 169–197). An account of all departments is given.

On the Wall Corrosion of the Blast Furnace. N. Nakamura. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1026–1028). Physical properties and analyses are listed for several samples of brick from the stack and hearth before blowing-in and after blowing-out, together with a diagram of the lining of the furnace wich was badly corroded. Glass, kaliophilite and zincite were found in areas of attack.—K. E. J.

Experience with Sinter Burden in Swedish Blast-furnaces. Ulf Notini. (*J.I.S.I.*, 1958, August, 322–326). [This issue].

Blast-Furnace Operation with a Top-Gas Analysis Meter. K. Yasuda. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 943–945). Variations in the CO_2 content of the top gas are examined for conditions of slipping, checking and hanging; the CO_2 contents are also compared with variations in the S and Si contents in the iron when the furnace is in poor condition or recovering.—K. E. J.

PROPERTIES, TREATMENT AND USE OF SLAGS

Modern Ideas on the Constitution of Molten Slags and the Thermodynamic Activities of Their Constituents. M. Rey. (*Centre d'Études Sidérur.*, 1954, pp. 94). Chemical aspects of structure, affinity for oxygen, and the molecular interpretation of chemical reactions in slags and the ionic interpretations are discussed. Methods of measurement of thermodynamic quantities and their phase diagrams and the relation between them and to structure are described with illustrations from binary and ternary systems. **Viscosity and Structure of Liquid Slags.** P. Kozakevitch and G. Urbain. (pp. 111). Theory, X-ray data, transport numbers and values for viscosity are discussed and the systems CaO–MgO–Al_2O_3–SiO_2. CaO–Al_2O_3–SiO_2, CaO–MgO–Al_2O_3–SiO_2, CaO–FeO–MnO–SiO_2 and the ternaries, the effects of TiO_2 and Cr_2O_3, and the CaO–FeO–P_2O_5–SiO_2 system are reviewed. Methods of viscosity measurement are then described and, in a supplement, the effects of Al_2O_3 on blast furnace and steel furnace slags are considered.

Phase Equilibria at High Temperatures in Iron Silicate Systems. A. Muan. (*Amer. Ceram. Soc. Bull.*, 1958, Feb., 81–84). Effects of O_2 in the gas phase are worked out. The Fe–O, FeO–Fe_2O_3–SiO_2 systems are shown.

Reactions between Molten Slags Containing TiO_2 and Pig Iron. R. Sato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 928–930). Inter-relationships are shown between CaO/SiO_2 ratio, TiO_2 in the slag and Si and S in the metal for electric furnace smelting; and between the CaO/SiO_2 ratio, FeO in the slag, and Si and S in the metal for blast-furnace smelting.—K. E. J.

Structural Interpretation of Immiscibility in Oxide Systems: III. Effect of Alkalis and Alumina in Ternary Systems. E. M. Levin and S. Block. (*J. Am. Ceram. Soc.*, 1958, **41**, Feb., 49–54). The effects of homogenizers are explained on various postulates. B does not act as a homogenizer. Two methods for determining the amount required for complete miscibility are given.

Study of the Properties of Hydrogen Dissolved in Liquid Slag by the E.M.F. Method. L. N. Barmin, O. A. Esin and S. K. Chuchmarev. (*Izvest. Akad. Nauk, Otdel. Tekhn.*, 1957, (9), 114–118). [In Russian]. In the investigation described, the behaviour of a hydrogen electrode in slags was studied, two types of oxygen electrode (gaseous and magnesia) being compared. Most experiments were with CaO–Al_2O_3–SiO_2–MgO slags (mol. fractions 0·34–0·64, 0·07–0·29, 0·06–0·59, 0–0·08, respectively). A reversible hydrogen electrode could be realized comparatively easily in the absence of easily reducible oxides, and magnesia in contact with the liquid slag functioned as an oxygen electrode. The experiments showed that the activity of water in slag is proportional to the square root of the activity of the lime, suggesting that hydrogen in slag exists in the form of hydroxyl anions. The authors suggest that from the e.m.f. of a hydrogen-oxygen cell with fused slag the basicity of the latter can be found.—S. E.

On Basicity and Potential of Slag. K. Sawamura. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 948–949).—K. E. J.

Microstructure of Slags Containing TiO_2. I. Microstructure of the Slag System CaO-TiO_2-SiO_2. II. Effect of Al_2O_3 and MgO on Microstructure of Slags. R. Sato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 869–870; 870–872). I. An equilibrium diagram showing the important parts of the CaO–TiO_2 system is given. II. Structural diagrams are given, to show the compounds formed in the CaO–TiO_2–SiO_2–Al_2O_3 and CaO–TiO_2–SiO_2–MgO systems.—K. E. J.

PRODUCTION OF STEEL

Metal Scrap Disposal. J. Wojtyna and Z. Mikolajczyk. (*Prz. Techn.*, 1956, **77**, Dec., 542–546). [In Polish]. The author emphasizes the importance of utilizing metal scrap for the Polish Iron and Steel Industry and discusses different technical and economic problems connected with it.

Report of the Heat Economy Sub-division of the Co-operative Society for Research into Iron and Steel Techniques. I. (*Tetsu-to-Hagane*, 1957, **43**, Oct., 1159–1166). [In Japanese].

Oxygen in Steelmaking. J. A. Charles. (*Research*, 1958, **11**, Mar., 102–107). A general review.

Some Patterns of Gas-Mixing in Metallurgical Furnaces. E. E. Sjöstrand. (*Jernkont. Ann.*, 1958, **142**, (1), 15–33). A review of published research during the last 20 years. The basic work by Rummel et al., theory and experiments, new methods of studying flow of gases, and some practical results are given.

Product Quality—Keynote of Drive Systems Engineering. E. H. Browning and L. F. Stringer. (*Iron Steel Eng.*, 1957, **34**, Dec., 114–122). This paper discusses the new emphasis on quality production in the American steel industry and describes a number of new developments which are essentially geared to produce higher grade steels—generally these developments are in control mechanisms and the authors describe electric arc furnace regulating systems, card programmed automatic screw-down control for reversing mills, hot and cold strip mill and rod mill control and electrolytic tinning line control.—M. D. J. B.

Experience in Using LP-gas in the Steel Works. D. Yoshinari. (*Tetsu-to-Hagane*, 1957, **43**, 1021–1023). Some physical properties of LP gases (propane, but-1-ene, butane and homologues) are listed and details are given of supply systems for butane gas.

Flame Radiation in a Furnace. T. Shirasawa. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 963–965). An experimental instrumented oil-burning furnace is described. Analyses are given for three types of heavy oil used. The effects on emissivity and temperature of variation in the atomizing medium and pressure, in the quantity of fuel and in the type of fuel are shown graphically.—K. E. J.

The Equilibrium between Sulphur in Liquid Iron and H_2S-H_2 Gas Mixture. Z. Morita. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 926–928). The furnace designed for equilibrium measurements is described, and equilibrium data are given for temperatures of 1550°, 1650° and 1750° C.—K. E. J.

Safety at the Broken Hill Proprietary Steelworks. J. E. Lewis and R. G. McLennan. (*Proc. Australasian I.M.M.*, 1957, Dec., 131–148).

On the Molten Metal Temperature after Bessemerizing. S. Muramatsu. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1033–1034).—K. E. J.

Use of Oxygen for Producing Steel in Basic Converters Abroad [Outside Russia]. (*Kislorod*, 1957, **10**, (4), 43–44). This short article is a useful summary of the number and capacity of basic converters using oxygen in Austria, Canada, U.S.A., Germany, Brazil, Japan, Holland and India.—B. S.

Effect on the Mechanical Properties of the Hydrogen Content of Converter Steels Blown with an Oxygen-Steam Mixture. A. Krüger and E. Schmidtmann. (**Stahl Eisen*, 1957, 77, Dec. 26, 1868–1873). Hot working of the steels reduced the hydrogen level to about 50% of that of the molten metal at the end of the blowing period. This effect was more pronounced in killed steel than in rimming steel. No difference with steels blown without steam addition was found in the mechanical properties, in the structure, working properties, in the structure, working properties and surface-treatment and finishing behaviour.

Equipment for the Iron and Steel Industry. II. Steelworks. (*Technique Moderne*, 1957, **49**, July). **Evolution of the Capacity of Open Hearth Furnaces in France.** M. Mallevialle. (335–338). Furnaces of over 100-t capacity are surveyed. **Control of Open Hearth Furnaces Heated with Fuel Oil.** F. Bourdillon. (338–340). The special case of a 160-t furnace with regard to oil supply, pressure and temperature and their adjustment, and control of combustion is reviewed. **Arc Furnaces for Steel Melting in the Iron and Steel Industry.** R. Boutigny and C. Barbazanges. (341–348). Statistics of production from arc furnaces are given and the development of the furnace is outlined and illustrated with heat balances, power requirements, transformer capacity, electrodes, refractories and an account of control. Steel making is then reviewed and new procedures such as the use of O_2, degassing, electromagnetic stirring, and a comparison of costs with the O.H. furnace are considered. **Breakage of Slags and Ashes from Basic Bessemer Furnaces.** R. Beck. (360). Use for road-making is briefly considered. **Steelworks Auxiliaries.** R. Petitjean. (425–430). A review of ladle cars, mixers, scrap presses and handling arrangements.

On Operating Improvements of Siemens Furnace. Y. Okada. (*Tetsu to Hagane*, 1955, **41**, Sept., 1019–1021). [In Japanese].—K. E. J.

Straightening Networks of the Air Checkers in Open Hearth Furnaces. I. B. Gol'denberg. (*Stal'*, 1957, (12), 1094–1096). A study of the movement of products of combustion in air slag pockets and in the space above the checkers shows non-uniformity in velocity distribution across the sections. A method of reducing this has been developed at Magnitogorsk and elsewhere by placing a correcting network of silica bricks at the entrance to the checkers, which increases the life of the checkers to 50–60% of the period of the campaign. Fuel consumption per ton is reduced by 9% and waste gas temperature is reduced. The design and a plan of the movement of the products of combustion are given and temperatures with and without the correcting networks are shown. The slag pocket is connected with the space above the checkers in the manner illustrated. The entrance to the chamber is widened to 30° on one side and constricted to 12° on the other. The latter has little effect on movement but the former produces a section of recirculation. An effective method of producing uniform flow is a resistance device in the form of a network across the sectional area. The calculation of its resistance is simple and the most stable and lasting construction can be determined.

Bottoms for Basic Open Hearth Furnaces. S. Wortman. (*Iron Steel Eng.*, 1957, **34**, Nov., 127–133). The author discusses the progress made during the last decade in the construction and maintenance of O.H. furnace bottoms. He indicates that further progress will follow the lines of faster installations of relatively expensive bottoms, improved drainage by better contour maintenance, better and specially graded fettling materials, and adoption of some features of European practice.—G. F.

Operating 185-ton Open Hearth Furnaces on Natural Gas. L. P. Bedelyan, I. G. Zhilyakov, V. M. Kanevskii, N. I. Ryaev and A. I. Urinson. (*Stal'*, 1957, (12), 1082–1085). From experience in the U.S. it was decided to feed at 10 atmos. to atomize fuel oil and obtain a good flame. Two gas feeds were provided, one at 10 atm for atomization and one at 3 for combustion. A water-cooled 2-stage burner is shown with full details of fuels for all stages of the heat. Productivity is not reduced if superheated steam is used for carburetting with fuel oil. Natural gas with 25% fuel oil is not inferior to a fuel oil flame. Difficulties were met with in forming high-pressure joints. Research is needed on the use of natural gas at 250–300° and also with a pressure of 13–15 atm.—B. S.

Investigations and Controls of Open Hearth Production Problems. A. V. Lang and T. A. Cleary jun. (*Blast Furn. Steel Plant*, 1957, **45**, Dec., 1407–1412). An account is given of the application of simple statistical principles to the study of O.H. practice at the Youngstown Sheet and Tube Co. Ohio. Factors affecting the rate of production were studied in particular.—B. G. B.

Study on the Operation of Furnaces by Flame-Radiation Measurement. H. Shimizu. (*Tetsu to Hagane*, 1955, **41**, Sept., 1031–1033). [In Japanese.]

Automatic Control of Fuel in the Open Hearth Furnace at the Yenakievsk Plant. Y. N. Tulуevskii and V. M. Klimenko. (*Stal'*, 1957, (12), 1086–1093). The scheme of automatic control is subordinated to the basic principles of thermal regulation with maximum heat input compatible with conditions of combustion, heat transfer, and reserves of draught. This gives control of heat input or of roof or checker temperatures with regard to the peculiarities of each heat. When units are developed to fix bath temperature and to avoid incomplete fuel combustion these can be included in the scheme. Applied to 150-t furnaces, a reduction in fuel consumption of 6% is obtained, with improved productivity and increased furnace life.—B. S.

The Use of Oxygen in the Open Hearth Scrap Process. K. G. Trubin. (*Use of Oxygen in Steelmaking Processes, U.S.S.R. Academy of Sciences, Ministry of Iron and Steel, Moscow*, 1955, *Symposium under the editorship of I. P. Bardin*, 8–17). [In Russian.] T. states that the introduction of O_2 into the furnace chamber of oil-fired O.H. furnaces was first carried out at the Krasnoye Sormovo works by V. V. Arkhipov in 1933–34 at the same time as experiments were being made at the Hammer and Sickle Works where O_2 was introduced through the checkers. Systematically organised investigations of methods of utilising O_2 in oil-fired O.H. furnaces began only in 1945 under the general direction of I. P. Bardin and under the scientific management of K. G. Trubin and M. A. Glinkov. These investigations continued until 1950. Trials were begun on a 10-t furnace and continued on a 70-t furnace. T. describes the methods used for intensifying combustion and gives details of the pytotechnic effect of the O_2 flame. Later investigations included the use of an O_2 jet preheated to 1400° C to cut up scrap already charged to the furnace. The disadvantages of this method are stated. O_2 was next used for direct oxidation of the liquid bath. The time of two to two and a half hours required to effect a carbon drop from 0·1 to 0·04% was reduced to fifty minutes. Under a silica roof, with a normal degree of air enrichment (up to 20 to 26% O_2) and with an accelerated rate of charging, output was increased by 22 to 48% with a drop in fuel oil consumption of 20%. Oxygen consumption was 1147 cu ft per ton of steel. Higher O_2 enrichment was limited by the silica roof temperature. With a chrome-magnesite roof, 28 to 30% O_2 in the air during charging and melt-down and with a heat input of 2200 to 2300 kg per hour of oil during charging and 1800 to 1900 kg per hour during melt-down and 1100 to 1200 kg per hour during the boil, furnace productivity was increased by more than 70% and heat consumption was reduced by 20%. **The Use of Oxygen for Intensifying the Open Hearth Process at the Hammer and Sickle works in Moscow.** P. Ya. Barzdain and V. P. Tunkov. (18–45). The authors first discuss the thermodynamic variables involved in using O_2 in oil-fired O.H. furnaces operating on the scrap process. Burner designs are described. Details of the separate periods of the heat with various degrees of enrichment are presented. The use of O_2 as a tool for aiding melt-down and accelerating oxidation reactions during the boil is described. Details are given of heats using O_2 in different ways simultaneously (the " complex " method) with silica and with basic roofs. Details of the period for which O_2 is used in different ways and at different times during the progress of the heat and for different types of steel are given. The effects on steel properties and on the refractories of the furnace linings are discussed. The Hammer and Sickle works has used O_2 in the following ways: (1) through burners in the end walls to enrich the air and intensify combustion; (2) by jet through a water-cooled nozzle or through an unprotected iron pipe direct on to the bath to accelerate melt-down; (3) by immersing a jet in the liquid bath to accelerate oxidation reactions; (4) by the " complex " method. A final comparison of these methods depends basically on the O_2 consumption per t of steel. The most effective method, as regards both output and reduction in fuel consumption, was the " complex " method. The following conclusions are based on three years' experience: (*a*) provided the silica roof is not overheated, O_2 fed through burners does not adversely affect the main roof and a beneficial effect is obtained in the checkers because of the reduction in the amount of waste gases; (*b*) the harmful effect of a jet in the furnace chamber when used to melt down the charge and to blow the bath (increased production of dust, etc.) can be reduced by careful control of the way in which the jet is introduced. Silica roof life on the 70-ton furnaces at the Hammer and Sickle works was 191 O_2 heats, checker life being 220 heats but, after 1949, these figures were increased to 241 heats for roofs and 257 heats for checkers during the last nine months of 1951. There was a monthly increase in steel output from 1949 to the end of 1951 and O_2 consumption rose from 6000 tons in 1949 to 22000 tons during the last nine months of 1951. **Thermal Conditions in Open Hearth Furnaces, Using Oxygen-Enriched Air (Scrap Process).** M. A. Glinkov and V. I. Mitkalinnyi. (46–48). The authors discuss the theoretical fundamentals of the use of oxygen. They describe optimum burner design for O_2 injection and give details of thermal inputs for both carbon and high-Mn steels. Graphical data are presented on flame temperatures with various degrees of enrichment with both acid and basic roofs. The authors then deal with thermal conditions in the checkers and in the waste gases in the down-takes and in the waste gas in front of the damper. **The Theory of Intensifying the Open Hearth Process By Means of Gaseous Oxygen.** E. V. Abrosimov. (69–79). A. considers various methods of applying O_2 and describes particularly its use for cutting up the charged scrap and for direct oxidation of the elements in the bath in the production of medium and low carbon steels. **Oxidation of Metal By Oxygen in the Open Hearth Bath.** V. A. Kudrin. (80–92). K. deals with the examination of both the steel and slag samples from the bath and discusses the relationship between the O_2 content of the metal and the C content of the pure boil. He gives details of changes in bath composition along the furnace axes. The phenomenon of short time super-oxidation of the bath is described. It was

found that the over-oxidised zone of the bath near to the point of insertion of the oxygen lance was soon diffused throughout the bath after the O_2 blow was finished and the content was reduced to normal. The period of "accumulation" of O_2 in the bath lasts not longer than one to two minutes. The period of the pure boil can be considerably reduced when blowing the bath with O_2 without any danger of over-oxidising the metal. The editor of this symposium, however, thinks this latter statement to be premature in view of insufficient research on this point. **Preferred Location of the Carbon Drop Reaction in the Open-Hearth Furnace Bath.** E. V. Abrosimov and V. A. Kudrin. (93–114). The point of preferential occurrence of the carbon drop reaction was found to be the middle of the bath. For some time after the end of the oxygen blow, the boil proceeds as in casts made without O_2. Thus, the intensification of the boil by O_2 injection, besides being caused by the intensive feed of O_2 to the place of reaction, is also due to the fact that the centre of the bath, otherwise somewhat inert, is artificially drawn into the active sphere of the carbon drop reaction. **The Quality of Steel Made with Oxygen.** I. I. Ansheles. (115–141). Comprehensive data are presented on the longitudinal and transverse properties of steel produced with and without oxygen. A number of interesting points is made such as, for instance, that, if all the heats to which O_2 was fed for direct oxidation were divided into two groups depending on the duration of the blow, there would emerge a clear tendency for the amount of inclusions to increase as the period of refining decreases. Reduction of area and elongation tend to exhibit a peak at 25 min of injection, while impact strength steadily increases up to 38 min of O_2 blowing. **The Brown Fumes Problem with the Oxygen Blow.** Yu. V. Kryakovskii. (142–157). Investigations were based on the application of O_2 through the burner direct to the bath. Dust accumulation was measured at many different points in the furnace system. The mechanism of dust formation and details of granulometric and chemical composition are given. It is concluded that: (1) dust formation is not uniform during the various periods of a heat, being highest during melt-down; (2) the use of O_2 for intensifying combustion during charging does not materially affect dust formation; (3) direct application of O_2 to the bath increases the formation of dust ten to forty times; (4) to reduce dust formation, O_2 must be injected into the bath at low pressure, with deep immersion of the lance and when the carbon content of the metal is low; (5) the chemical composition and physical state of the "melting dusts" are the same for an oxygen-blown bath as for a normal heat. It is not, therefore, the quality of the dust which has an adverse effect on refractories when O_2 is used, but the amount. **New Method of Producing Stainless Steel with Oxygen in the Electric Arc Furnace.** Ya. M. Bokshitskii. (158–179). Until 1948–49, stainless steel was produced at the Elektrostal works by the normal method used for alloy steels, i.e. without oxygen injection. This had the following disadvantages: (*a*) it was impossible to lower the C content of the bath after melt-down and to control refining; (*b*) the sudden increase in the number of off-heats when using more than 40% scrap in the charge; (*c*) the high percentage of rejects on account of blow holes (40% of the steel from 136 heats made in 1950 was rejected for blow holes); (*d*) it was not possible to make steel with less than 0·10% C; (*e*) too much special low C charge (0·03 to 0·04% C) had to be used. This amounted to 30 to 35% of the charged weight. In 1948, an O_2 plant was installed to supply 350 to 1235 cu ft per min to the 15-t arc furnaces. Details of furnace power characteristics and of the compositions of the stainless steels produced are given. Seventy-four trial heats were produced and a method for melting Cr–Ni, Ti-stabilised austenitic steels was developed. The hearths and walls of the furnaces were rammed with a mixture of tar and magnesite. Precast, rammed magnesite blocks were used for the side walls. Refractory life was improved by shortening the heats and modifying the thermal conditions. The cooling of the bath by the addition of a large amount of ferro-chromium five to fifteen minutes after the end of oxidation reduced wear of hearth and side walls. The period of melting the basic metallic charge was considerably reduced by increasing the amount of Si in the charge (high silicon scrap) and by the use of O_2. The use of fireclay instead of lime and fluorspar ensured a fusible, low melting-point slag during the entire blow. A single-slag process was employed. The carbon content of the 18/8 stainless steels was 0·07 to 0·08% max. Rejects for blow holes, formerly 6·9% by weight, were eliminated. Lower grade charge was used. The new technique for producing stainless steel developed at the Elektrostal works has been successfully introduced at the Red October plant in Stalingrad, at the Dnyeprospetsstal works in the Ukraine and at Kuznetsk in Siberia.—R. S.

On Slag Basicity in Open Hearth Furnace Operation. H. Kunitake. (*Tetsu to Hagane*, 1955, **41**, Sept., 949–951). [In Japanese.] Data are given for the effect of slag basicity (V-ratio) on desulphurisation ratio for molten metal having melt-down sulphur contents between 0·02 and 0·06%.—K. E. J.

Oxidation in the Oil-fired Basic Open-Hearth Furnace during the Melting Period. Effect of Scrap on Bath Operation. K. Tajiri. (*Tetsu to Hagane*, 1955, **41**, Sept., 951–953). [In Japanese]. An oxygen balance during the melting period is given. An approximately linear relationship is shown between amount of scale on the scrap surface and the surface/weight ratio, which is related to the scrap density and type. Relationships are also shown between the surface area of the scrap and the amounts of oxygen in oxidised scrap and scale and the yield of steel.—K. E. J.

Study on Melting Practice of Tilting Open-Hearth Furnaces. M. Oishi. (*Tetsu to Hagane*, 1955, **41**, Sept., 953–955). [In Japanese.] A considerable amount of operating data is given, including changes of metal and slag analyses, changes of bath temperature, slag fluidity and slag thickness with time, and the relationship between average fluidity of the slag and the rate of rise of temperature.

Aerodynamic Constitution of the Open-Hearth Furnace. IV. Functions of the Furnace Chamber. H. A. Hasimoto. (*Tetsu to Hagane*, 1957, June, **43**, (628–632). [In Japanese.] Model studies to obtain the best chamber flow indicate (*a*) the chamber spaces should be balanced in front of and behind the burner line, and thus the walls should be equidistant from it; (*b*) the shoulder angle should be 40–60°, preferably 53°; (*c*) the height of the main roof should be 37–55% of the chamber width, preferably 46% but less for large furnaces; and (*d*) the length should not exceed three chamber widths, while the bath length should be about 2·6 chamber widths or 3 bath widths. **V. Functions of the Air Uptake. VI. Functions of the Furnace Head.** (July, 695–699; 699–703). V. Model studies of a single-uptake furnace show that the uptake width should be 50–60% (preferably 50%) of the chamber width, and the length should be one-third of the chamber width. In the central uptake design, the width should be four-sevenths of the head width, but equal to it in the spread uptake design. VI. Optimum head dimensions derived from model studies are given. Side-wall wear may be reduced without affecting the incoming air-flow by lowering the head roof or the end wall to the end.—K. E. J.

Desulphurization in the Basic Open-Hearth Furnace. K. G. Speith, H. vom Ende, and G. Mahn. (*Stahl u. Eisen*, 1958, **78**, Jan. 9, 27–34). The course of desulphurization for each of 850 heats was followed and the effect of Mn, C, quantity of slag, temperature and rate of melting-down studied. High Mn content gives low S levels, for the same Mn level the S will be lower the lower the temperature. Desulphurization is better the higher the lime content of the slag. In reducing slags S is combined mainly as sulphide but in oxidizing slags mainly as sulphate.—T. G.

The Desulphurisation of Molten Steel by CaC_2 and CaO. C. Yoshii and K. Shimanaka. (*Tetsu-to-Hagane*, 1957, **43**, Aug., 807–812). [In Japanese.] Samples of 200–350 g of low-carbon steel were melted in a magnesia crucible and deoxidized by Al, and then had their surfaces covered by desulphurising powders for reaction at 1550–1600° C. With CaO, the sulphur content decreased from 0·09% to 0·03% after 15 min., but then increased, the O_2 content increasing simultaneously; additions of carbon and Si, however, brought the sulphur content to 0·01%. With CaC_2, acting as both desulphurizer and deoxidizer, the sulphur content fell from 0·1% to 0·003% in 15 min. and continued to decrease.—K. E. J.

Manufacture and Properties of Semi-killed Steel Plates by Centre-runner Deoxidation. A. Dote. (*Tetsu to Hagane*, 1955, **41**, Sept., 1027–1030). [In Japanese.] Details are given of practice and of the properties of the steel and plates when deoxidation is effected by Fe–Si, Al, Ca–Si, and Fe–Si–Al.—K. E. J.

Origin and Elimination of Hydrogen in Basic Open-Hearth Steels. W. L. Kerlie and J. H. Richards. (*Trans. A.I.M.M.E.*, 1957, **209**; *J. Met.*, 1957, **9**, Dec., 1541–1548). The authors have studied the variation in H_2 content of basic O.H. steels during refining and the effect of changing from steam to air atomisation. The water content of the furnace atmosphere, the slag basicity, and the degree of oxidation of the slag-metal system are shown to be the main factors governing the H_2 content of the steel.—G. F.

Elimination of Hydrogen in Molten Steel with Argon Gas Flushing. H. Ohi. (*Tetsu to Hagane*, 1955, **41**, Sept., 1033–1034). [In Japanese.] Details are given of argon flushing practice for basic arc and basic O.H. furnaces, and the variations of hydrogen and nitrogen content during the refining period are shown.

Here's a New Gunning System. (*Steel*, 1957, **141**, Oct. 21, 88). A description is given of a new refractory gunning system for O.H. repairs. The mix (Permanente K/R 165) is made from periclase grains, and is shot from the gun at 200 lbs/min, being continuously fed to the machine through 2 hoppers. The machine is designed for use on the charging platform and is operated by 3 men—D. L. C. F.

New Arc Furnace Has 66 kV. Transformer with On-Load Tap Changing. (*Metallurgia*, 1957, **56**, Nov., 242–243). The new 80-t arc furnace at Samuel Fox Ltd. has a 20,000 kVA transformer operating directly from a 66,000 volt supply, and employing on-load tap-changing equipment. Details of the installation are given.—G. F.

Large Electric-arc Furnace Steelmaking Experience in the U.S.A. A. C. Ogan and D. J. Carney. (*J.I.S.I.*, 1958, August, 307–314). [This issue].

Ladle Slag-Refining of Electric Furnace Steel. R. Perrin. (*J. Met.*, 1957, **9**, Dec., 1517–1520). A description is given of the Perrin process for rapid desulphurization and deoxidation of electric steel. The metal is tapped into a ladle containing a liquid slag of 42% Al_2O_3, 53% CaO, < 5% SiO_2, and < 1% FeO. The possibility of applying similar processes to other steelmaking units and to blast furnaces is discussed.—G. F.

Case Studies in Cast and Rammed Arc-Furnace Roofs. J. D. McCullough. (*J. Met.*, 1957, **9**, Dec., 1521–1524). Cast or rammed monolithic constructions in centre sections of arc-furnace roofs have proved a practical means of reducing refractory costs. The author describes four typical examples of such installations.—G. F.

Analysis of Arc Furnace Control. J. H. Kogen. (*J. Met.*, 1957, **9**, Dec., 1525–1528). To eliminate the guesswork in choosing components, making adjustments, and modifying control systems, the author has devised a method for working out problems in arc furnace control. The principles and limitations of the analysis are described.—G. F.

The Latest Edgar Allen Special Alloy Tool Steels. (*Edgar Allen News*, 1957, **36**, Dec., 272–274; 1958, **37**, Jan., 9–10. Double Six Super Die Steel for cold work is described and its properties are given and uses illustrated as are Double Seven non-shrinking air-

hardening steel and K9 oil-hardening steel. Minerva H.C. steel for punches, dies and shear-blades and V.S.4 shallow hardening steel for cold heading dies are then considered.

A Satisfactory Base-Quality Steel for both Riveted and Welded Structures. J. O. Jackson. (*Weld. J.*, 1957, **36**, Dec., 1184–1188, discussion 1188–1194). It is suggested that ASTM A7 be revised, adding a carbon limitation of 0·30% on ladle analysis, and so dispensing with A373 grade.

Study on the Toughness Improvement by Addition of the Small Amount of Ferro-Titanium to Special Steel. T. Saito. (*Tetsu to Hagane*, 1955, **41**, Sept., 927–929). [In Japanese.] Twelve steels (analyses given) were tested, the final titanium contents ranging from a trace to 0·06%. Considerable increases in toughness were found with Cr–Mn, Cr–Mn–Mo, Cr–Mo, Ni–Cr–Mo and Si–Mn–Cr steels, and small increases with Mn and Cr–Mn–Mo–V steels.—K. E. J.

Heat-Resistant Steel: Czechoslovakian Development of Low-Cost Alloy. (*Iron Steel*, 1957, **30**, Nov., 602). Details are given of the properties of a new heat-resistant steel developed in Czechoslovakia and containing 1% C and 30% Al. Called "Pyroferal," it is claimed to be superior in heat resistance to Cr or commercial austenitic Cr–Ni steels.—G. F.

On the Life of Large Ingot Moulds Made with Nodular Cast Iron. T. Kitashima. (*Tetsu to Hagane*, 1955, **41**, Sept., 993–1000). [In Japanese.]—K. E. J.

Test Results of Ingot Moulds Made from Ductile Iron. K. Sawada. (*Tetsu to Hagane*, 1955, **41**, Sept., 1000–1001). [In Japanese.] Results from three works show that ductile iron moulds have a life (in heats) some 70% greater than that of grey iron moulds. The lower the ratio of mould weight to ingot weight, the longer the life.—K. E. J.

The Study of Slag-Metal Mixing Efficiency by Models. C. E. A. Shanahan and F. Cooke. (*J. App. Chem.*, 1957, **7**, Dec., 645–654). Using sodium amalgam as "metal" and sulphuric acid as "slag" the most effective method of mixing was shown to be pouring the metal into the slag and that degree of mixing depends on height of drop and rate of pour. Blowing with gas and rabbling were less effective, while a simple converter model gave efficiencies comparable with those obtained by pouring at low flow rates. Another system with hexane and $ZnCl_2$ solutions containing methyl red was also examined to assist in correlation with full-scale plant.

Heating Feeder Heads by Induction Currents. S. P. Bakumenko and A. M. Svistunov. (*Stal'*, 1957, (12), 1077–1081). Discard for piping was reduced to a maximum of 5% by means of the feeder head shown, for ingots of 2·6–3·5 t. The ingots were of quality equal to conventional ingots and costs are lowered 7–9%. The structure, chemical and mechanical properties and non-metallic inclusions are described. Compared with refractory hot tops 10–13% metal is saved.—R. S.

Studies on Improvement of Molten Iron. III. Comparison of Scale Addition with Blowing Oxygen into Molten Iron. T. Tottori. (*Tetsu to Hagane*, 1955, **41**, Sept., 1013–1015). [In Japanese.] Details are given of the composition of two original irons, and of the compositions, mechanical properties and structure of the molten iron untreated, after scale addition, and after blowing. The ductility was most improved by blowing with oxygen and adding Si and Mn. The effects of the two treatments on the ability to form spheroidal graphite iron are also discussed.—K. E. J.

Study of Small Ingots. H. Narisato. (*Tetsu to Hagane*, 1955, **41**, Sept., 1023–1025; 1025–1027). [In Japanese.] I. In bottom-poured ingots 140 cm high, solidification and temperature changes in the moulds with time (up to 40 min) are studied. II. A comparison is made between large and small ingots for segregation in killed, semi-killed and rimming steels. Differences in rising velocity in the mould produced by improved types of refractory are charted.—K. E. J.

Semi-Continuous Casting of Stainless Steel. G. I. Kozlitin and L. N. Kolybalov. (*Iron Coal Trades Rev.*, 1958, **176**, Jan, 3, 31–33). This is a condensed translation of the article in *Stal'*, 1957, (3), 209–213. Abstracted, *J.I.S.I.*, 1958, Feb., 182.

Some Considerations on Longitudinal Cracks in Ingots. S. Iwamura. (*Tetsu-to-Hagane*, 1957, **43**, 1055–1057). [In Japanese]. The influence of carbon content (0·12–0·55%) on longitudinal cracking is considered for carbon, Cr-Mo and Ni-Cr steels.—K. E. J.

Influence of Pouring Refractories on the Formation of Macro- and Micro-Inclusions in High Carbon Chromium Steel. I. Y. Kotani. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 899–901). The chemical, physical and thermal properties of Roseki, chamotte, high-alumina, flint clay, soft clay and spinel refractories are compared with the resistance to erosion by slag and steel and with the macro- and microscopic non-metallic inclusions formed in high C Cr steel.—K. E. J.

PRODUCTION OF FERRO-ALLOYS

A New Method of Obtaining Decarburised Ferro-Chromium. I. D. Kirichenko. (*Stal'*, 1958, (2), 131–137). A method was developed for the decarburization of solid ferro-chromium under vacuum by means of iron ore or of previously oxidized ferro-chromium containing 0·01–0·03% C and having a low Si content. A large scale laboratory device for achieving this is described and illustrated.

Production of Silicon Pig Iron. P. Nicolae. (*Met. Constr. Masini*, 1957, **9**, (8), 15–22). [In Rumanian]. Owing to the fact that the native Mn ore has a high P content, production of spiegeleisen is not possible within the limits allowed by the standards. But production can take place if coke is used with a very small P content and if steel scrap is added to dilute the P content in the iron produced. Materials used were limonite from the Teliuc region and Krivoi-Rog Ores.

FOUNDRY PRACTICE

Technical and Economic Considerations for Obtaining Sound Castings. G. Barchiesi. (*Fonderia*, 1957, **6**, Dec., 517–523). [In Italian]. The article reviews modern techniques currently used to ensure the production of high grade castings. A number of recommendations are given.—M. D. J. B.

Design of Castings with Regard to Moulding. (Part 2). A. Östberg. (*Gjuteriet*, 1958, **48**, Jan., 1–7). For easier moulding, projections can be redesigned or their positions altered. Design should eliminate narrow ribs of sand, and core prints should be considered. Several separately cast components instead of one large, complicated casting can reduce costs. The text is illustrated with numerous figures.

Investigation of Cast Iron Parts of Foreign Motorcars. D. P. Glukhov. (*Lit. Proizv.*, 1955, (12), 9–12). [In Russian]. Cast iron parts from cars delivered to the U.S.S.R. between 1945 and 1954 have been examined and results are tabulated. The cars include Packard, Bedford, Dodge and Ford, Canada and USA, Lincoln, Cadillac, Studebaker Chrysler etc. The microstructure of the parts has been examined, also the hardness, chemical composition etc.—L. H.

Nitrogen in Cast Iron. L. I. Levi. (*Lit. Proizv.*, 1955, (6), 22–25). [In Russian]. The use of active nitrogen makes it possible to obtain from one charge, and indeed from only one ladle, irons of different mechanical characteristics according to predetermined specifications. The absorption of N_2 by metals in the converter process is explained by the fact that when blown in together with the O_2, it is subjected to the resulting intensive exothermal microreactions. These cause its dissociation to some extent.—L. H.

Machine Equipment of a Foundry. J. Horoszko. (*Prz. Odlew.*, 1957, **7**, May, 126–135). [In Polish]. A review of standard machines and foundry equipment produced in Poland is given, with diagrams and photographs. The following are discussed: sand conditioning machines, mixers, aerators, electromagnetic separators, screening machines, machines of assembly type and others.

The Principles of Organization in a Foundry. D. F. O'Connor and C. Morgani. (*Fonderia*, 1957, **6**, Dec., 531–538). [In Italian]. The article describes organization and method techniques in foundry work. The objective is increased productivity.—M. D. J. B.

Automation in the Foundry Industry and the Possibilities for its Future in Poland. J. Lempicki. (*Prz. Odlew.*, 1957, **7**, Aug., 226–231). [In Polish]. The basic terms used in automation are explained. The present possibilities of automation in Polish foundries are discussed.

Do-It-Yourself Builds a Modern Malleable Foundry. (*Eng. Foundryman*, 1957, **22**, Dec., 37). An installation of 2 cupolas, a sand-conditioning system, two annealing ovens and other equipment built by K. Futter and his assistant is briefly described.

Unsuitable Pig Iron Causes a Great Quantity of Casting Defects. R. Tyrlik. (*Prz. Odlew.*, 1957, **7**, Sept., 266–268). [In Polish]. The difficulties of finding the cause of defects which appear in the later stages of mechanical production are discussed and illustrated, with an example of a defect in part of the car M20 WARSZAWA. After thorough investigation the defects were found to be caused by the quality of pig iron, which could not be detected by chemical analysis.

Mechanism for Pore Formation in Solidifying Metals. W. D. Walther, C. M. Adams and H. F. Taylor. (*Trans. A.F.S.*, 1956, **64**, 654–664). Armco iron and four pure non-ferrous metals were cast into various shapes to test various predictions on the effects of dissolved gases on pore formation. It was observed that plates are more easily fed than bars, a very slight taper is sufficient for feeding a bar to complete soundness and that gas in solution limits the feeding range of a metal. Equations for pressure drop in a long cylinder casting, for heat flow and for metal flow in a partially solidified casting are given.

Quantitative Evaluation of the Susceptibility of Various Alloys to Shrinkage Defects. R. A. Flinn. (*Trans. A.F.S.*, 1956, **64**, 665–667). Steels are included in the data, but general calculations are presented.

Influence of Ti, Cr and Mo on the Fluidity of Molten Cast Iron. T. Hiromoto. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 993–994).—K. E. J.

Structure Diagrams for Iron Castings in Metallic Moulds. N. P. Dubinin. (*Lit. Proizv.*, 1955, (8), 15–16). [In Russian]. A study is made of the rate of hardening of castings under different conditions, in moulds with walls of various thicknesses, at different distances from the walls.—L. H.

Pad Washing with Carbon Arc Process. F. Newberry. (*Trans. A.F.S.*, 1956, **64**, 430–431). Grinding and cleaning costs are reduced by removal with Cu-clad C electrodes of gates, riser pads, fins, nails and excess weld deposits from steel castings.

Basic Cost Concepts for the Small-Medium Foundry. A. C. Sinnett. (*Trans. A.F.S.*, 1956, **64**, 167–170).

Some Aspects of Dust Suppression in Foundries. C. M. Stoch. (*Trans. A.F.S.*, 1956, **64**, 136–146). Both prevention and control are reviewed. The work of B.S.C.R.A. carried out with the support of the British Steel Founders' Assoc. is outlined. Local exhaust systems for grinding machines are described.

Foundry Goggles. First Report of the Joint Advisory Committee. A. M. Reid. (*Foundry Trade J.*, 1958, **104**, Mar. 20, 327–330). Laboratory ballistic trials are reported and recommendations are made.

VACUUM METALLURGY

Pressure Distribution Within a Vacuum Arc Furnace. J. W. Suiter. (*J. Electrochem. Soc.*, 1958, **105**, Jan., 44–46). Measurements were made by means of a controllable leak in a continuously-evacuated consumable electrode furnace. These agreed with calculations from kinetic theory.

Vacuum-Melted Steel, Titanium and Zirconium. (*Met. Treatment*, 1958, **25**, Feb., 74–76). A discussion of results obtained by

Wm. Jessop & Sons Ltd. and of their Vacumelt steels.

Huge Vacuum Furnace at Hollywood Heat Treating. (*Ind. Heat.*, 1958, **25**, Jan., 205, 207). A furnace 99 in. dia. × 120 in. deep holding a retort of working zone dimensions 54 in. dia. × 108 in. deep is briefly described.

The Effect of Melting *in Vacuo* on the Growth of Cast Iron. F. N. Tavadze and I. A. Bairamashvili. (*Lit. Proizv.*, 1955, (12), 23). The findings show that the solution of gases in the iron does not influence appreciably the growth of sulphur-containing cast iron in volume or weight.—L. H.

REHEATING FURNACES AND SOAKING PITS

How to Increase the Economic Efficiency and Utilisation of Large Furnaces in Rolling Mills. F. Vaniš. (*Hutník*, 1958, **8**, (1), 5–10). [In Czech]. Economic and technical aspects of the performance, design and operation of soaking pits and other furnaces are considered.—P. F.

Technical Progress in Reheating Furnaces for Rolling Mills. K. M. Golosman. (*Stal'*, 1958, (2), 171–178). Some new high output Russian soaking pits are described. The article also deals with some reheating furnaces having injection flameless burners and a productivity of 200 t/h. It also describes tower and horizontal heat treatment furnaces for continuous high-speed output of strip in coils. It outlines the fundamental difficulties associated with the planning of this type of furnace.—R. S.

On the Improvement Effected by Transferring Round Steel Billets in the Heating Furnace. K. Sato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 913–915).—K. E. J.

Selection of Heating Methods for Blanks in the Forge and Stamping Shops. V. N. Glushkov. (*Vestnik Mashin.*, 1958, (1), 56–62). The heating in the forging shop should develop along the lines of gasification, wherever possible, rather than change into a system of electric heating. The neglect of fuel oil as a source of energy for heating metals in forging shops is premature and incorrect in view of its great possibilities and low costs. In Germany the use of fuel oil for this purpose is preferred.—L. H.

On the Damage to the Refractory of a Furnace at a Steel Works. T. Otsuka. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 909–911). Comparative figures for refractory consumption and steel output are given for three years' operation of furnaces in the rolling, tube-making and forging shops.—K. E. J.

HEAT TREATMENT AND HEAT-TREATMENT FURNACES

Industrial Heating Equipment Highlights of 1957. R. E. Fleming. (*Steel Proc.*, 1958, **44**, Jan., 38–40). A review of ferrous and non-ferrous topics. Heat treatment of strip is included.

Changes in Linear Dimensions of Steel Specimens by the Conditions of Thermal Treatment. I. E. Brainin and A. V. Tursunov. (*Vestnik Mashin.*, 1954, (4), 65–67). The object of the tests was to determine the effect of tempering at various temperatures. The experiments showed that the linear dimensions of the specimens were affected by the thermal treatment. The residual specific elongation and the hardness of the specimens under various conditions of treatment such as various temperatures appropriate to the type of material, cooling with water or oil, etc., are considered for many types of steel.—L. H.

Steam Atmosphere Heat Treating. F. L. Spangler. (*Steel Proc.*, 1958, **44**, Jan., 35–37). Applications to parts made from ferrous and non-ferrous metals are summarized. Equipment is briefly reviewed and powder metal applications are referred to.

Investigations into the Thermal Treatment of Steels at Temperatures below 0° C. I. I. Burcioiu, C. Vitanescu and Gh. Sucila. (*Met. Constr. Masini*, 1957, **9**, (9), 1–10). [In Rumanian]. Ball-bearing steel, annealed at 850° increases in hardness when cooled to −60 to −70° C for a certain time, after which its hardness remains stationary owing to the stabilization of the residual austenite. Resistance to fracture is, however, lessened. Ball-bearing specimens cooled below 0° after a certain thermal treatment, are more stable, whilst, ordinarily treated, they increase their diameter by 6 to 9 microns, due to the transformation in time of the residual autenite into martensite with an increase in volume. **II.** Two types of tool steel have been investigated and the general conclusions reached show that cooling below 0° after annealing increases the hardness of all the steels investigated. Increase in resistance to wear was confirmed in all cases. Plasticity, however, has been lowered in almost every case. Cooling below 0° C is recommended for all steels except for one quality of high-speed steel.—L. H.

Causes of the Short Life of Springs. F. Beneš. (*Hutn. Listy*, 1958, **13**, (1), 22–25). [In Czech]. Causes of shortcomings in the quality of coil springs produced in Czechoslovakia are analysed. It is suggested that most of these could be eliminated by closer control of wire stock quality and of heat-treatment technology. The use of quenched wire for springs used in injection pumps is suggested; limited possibilities exist also for the use of patented wire. The possibility of resonance in the springs in use could not be eliminated as a contributory cause of frequent failures.—P. F.

Sulphidising of Chromium Stainless Steels. E. P. Pukhovskii, P. A. Zakharova, N. A. Shpigunova and G. P. Budayev. (*Metallov. Obrab. Met.*, 1956, (5), 40–43). The article reviews experience in the sulphidizing of Cr steels. Three compositions consisting of iron sulphide, graphite and potassium ferrocyanide were used at 560°, 650° and 750° C for various periods. Details of improvements to properties are given.—R. S.

Use of Beryllium Oxide for Beryllium Impregnation of Steel. V. A. Parfenov. (*Metallov. Obrab. Met.*, 1956, (3), 17–19). The article describes the necessary conditions for impregnating a carbon steel with Be so as to obtain sufficient depth of saturation and a hard diffused layer.—R. S.

Applications of Furnace Atmospheres. II. C. E. Peck. (*Ind. Heat.*, 1957, **24**, Dec., 2486, 2488, 2490, 2492; 1958, **25**, Jan., 56, 58, 60, 62, 64; Feb., 258, 260, 262, 264, 266, 268). The hardening of steels is reviewed with regard to the avoidance of decarburization, and dew points and carbon potentials are tabulated, gas carburizing and cabonitriding are then outlined. Some non-ferrous applications are considered and then sintering and powder-metallurgy applications. Furnaces are then reviewed and a general table is given summarizing the uses.

The Effect of Heating Rate on the Heat-Treatment of Stainless Steels. T. Mori. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1002–1004). Results are given for a steel containing 9·4% Ni and 19% Cr (analysis given). Rapid heating, as opposed to slow, increases the heating temp. at which the hardness maximum is found, and increases the magnetic susceptibility at heating temp. below 900° C (but reduces it for higher temperatures). It removes the high corrosion effect in 5% H_2SO_4 at 600° C. Its effect on recrystallized grain size is shown.—K. E. J.

Crankshaft Heat Treatment. (*Auto. Eng.*, 1958, **48**, Feb., 62–63). An illustrated account of the Scottish Stamping and Engineering Co. Ltd. installation at Ayr.

Hardening of High Speed Steel Tools of Greatly Varying Section. R. P. Leshchinskaya. (*Metallov. Obrab. Met.*, 1956, (3), 43–46). Attempts to eliminate the danger of cracks in heat treatment of heavy tools of complex shape by three-stage heating and stepped quenching were not entirely successful. If such high-speed tools are quenched to the martensite point with subsequent slow cooling (20 to 40°/h) in oil in the zone of martensite transformation down to 40 to 50° C, cracking is avoided.—R. S.

Intensification of the Cementation Process with Solid Carburizers for Motor Parts. A. M. Tarasov and M. R. Semenchenko. (*Metallov. Obra. Met.*, 1955, (6), 45–51). To increase the efficiency of furnaces for the cementation of motor parts requiring repeated heating with solid carburizers, it is suggested that higher temperatures than usual (900–910°) are employed. By increasing the temperature to 950° the efficiency was found to increase by 25–35%, without lowering the resistance qualities of the articles so hardened.—L. H.

Properties of Sylvine as a Medium for Heating Steel Articles for Tempering. E. A. Smol'nikov. (*Metallov. Obra. Met.*, 1955, (6), 25–32). Experiments and industrial practice have shown that it is possible successfully to use sylvine ore in electrodes and in crucible salt baths as a medium for heating articles made of carbon and alloy steels in the tempering process. The ore is equivalent in its effect and price to the technical mixtures used for these baths.—L. H.

Investigation of the Processes of Tempering in the Iron-Nitrogen System. V. G. Permyakov. (*Metallov. Obrab. Met.*, 1956, (7), 2–9). There is a great similarity between the processes of tempering quenched Fe–N and Fe–C alloys. In both, tempering begins with the breakdown of martensite on which the breakdown of residual austenite is superimposed above 190°–200° C. The nitrogen martensite, similar to the carbon martensite, possesses great hardness which, on tempering in the range from room temperature to 200–250° C, undergoes a further increase due to the precipitation of a highly dispersed nitride phase. With continuous slow heating, the breakdown of the nitrogen residual austenite occurs in the range of 190–200° C to 300–310° C. As a result of the breakdown of the nitrogen martensite and of the residual austenite, there is formed a mixture of ferrite and the nitride gamma phase of various degrees of dispersion. By changing the tempering temperature, the properties of the products of tempering of the hardened nitrided iron can be varied within wide limits.—R. S.

Isothermal Tempering of Springs and Coils from Steel 55 S 2. V. S. Men'shov. (*Metallov. Obra. Met.*, 1955, (6), 32–36). The technique of this process lies in heating to 850–880° and then cooling in a liquid medium at 340–380° during 5–7 min depending on the thickness of the articles. The results obtained in these experiments are tabulated and compared with the usual practice.—L. H.

Residual Stresses in Zonal Tempering by High-Frequency Currents. G. F. Golovin and D. A. Kotsylo. (*Metallov. Obra. Met.*, 1955, (5), 28–32). In zonal tempering near the boundaries of the tempered layers, the zones of residual stresses reaching 20 kg/mm² are detectable. The distribution of these residual stresses and their absolute values depend, in the first instance, on the distribution of hardness in the tempered layer. Tempering to a uniform depth on heating with a frequency of 2000 to 8000 cycles/sec gives a nearly uniform value of residual stress. The best temperature is found to be 200–250° when the minimum stresses are produced.—L. H.

Coagulation of the Carbide Phase in the Tempering of Steel. V. I. Psarev. (*Metallov. Obra. Met.*, (2), 1956, 2–8). A formula is derived to describe the relationship between the mean radius or the number of coarsening particles and the isothermal holding period. This calculation explains the laws governing the process of coagulation in steels. If the linear speed of growth of the coarsening particles and the changes to which they are subjected with time are factors directly determining the process of coagulation, then the diffusion of carbon is not the sole decisive elementary process in the coagulation of carbides. The linear speed of particle growth depends not only on the coefficient of diffusion but also on the concentration gradient, while the latter depends on the specific surface energy at the phase boundary. The higher this is the sooner the process of coagulation decays and the greater is the change in the linear speed with time for a given coefficient of diffusion.—R. S.

FORGING, STAMPING, DRAWING AND PRESSING

The Forging Industry, Past and Future. C. H. Smith jun. (*Steel Proc.*, 1958, **44**, Feb., 71–75). A statistical review of the growth of the industry with suggestions for expansion.

Properties of Industrial Forgings from Steel 20 KhM. N. I. Belan, V. V. Novikov and V. M. Kanfor. (*Metallov. Obra. Met.*, 1955, (5), 33–41). Industrial forgings of this steel in 145 mm sections have given, after tempering and annealing, practically the same properties in all the works. The tests extended over 1000–3000 h in the stressed and unstressed condition at 470° and 520°. The relation has been found between creep at a speed of 10^{-5} % per h for a time of 10^{5} h and the temperature.—L. H.

Wear of Drop Forging Dies. D. B. Smith, H. Southern and H. A. Whiteley. (*Steel Proc.*, 1958, **44**, Jan., 9–13). A study using radioactive tracers is described. Small pieces of activated NiSrMo No. 5 die steel were inserted and autoradiographs were made of the forgings produced. The activity of the scale was determined and the die was also examined. Further work is suggested.

On the Forgeability of the Transformation-free Alloy Ingot. I. The Relation of Compressibility and Cast Structures in Timken 16-25-6. T. Yamane. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1006–1007).—K. E. J.

Production of Forgings on Reduced Rolls. T. Rut. (*Prace Inst. Mech.*, 1954, **4**, (13), 64–77). [In Polish]. Types of reducer rolls and processes of pre-forming forgings by three methods: longitudinal, transverse and periodic, are discussed. Production efficiency on reducer rolls is found to be much higher than that with the use of hammers, the results obtained on an experimental three-high machine of the CNIIT Masz's design are discussed in detail.

Principles of Metal Forming Processes. T. Pelczynski. (*Prace Inst. Mech.*, 1954, **4**, (13), 1–20). [In Polish]. The production of many metal articles by the deformation method is considered to have the following advantages: economy of material, labour, tools and high quality of the final product. The equation of the modulus of deformation and strain, the mechanism of plastic deformation, internal strain, the influence of pressure on the properties and structure of the metal and the influence of the temperature of annealing on the properties of the material are discussed.

The Piercing of Tube Billets Using Water-Cooled Mandrels. M. M. Kaufman. (*Stal'*, 1958, (2), 144–151). Nearly all Russian tube plants are now experimenting with the use of fixed water-cooled mandrels. For the piercing of carbon and low alloy steels the most widely used mandrels have the following composition: C 0·15, Mn 0·30–0·60, Si 0·20–0·50, Ni 3·0–3·5%. CrNi mandrels containing 0·2–0·3% V are used for piercing high alloy and ball bearing steels.—R. S.

A New Single-Operation Precision Blanking Process. (*Machinery*, 1958, **92**, Mar. 28, 724–726). The system developed in Switzerland by Heinrich Schmid Co. is described. Press sizes are given.

The Ejection and Handling of Large Components in Pressworking. J. H. Stephens. (*Sheet Metal Ind.*, 1958, **35**, Jan., 23–32: discussion 32–34, 54). An illustrated account, including a discussion of shop layout, press speeds and operator safety.

Perfecting a Drawing Tool. A. I. Bogdashkin and R. I. Valentova. (*Stal'*, 1958, (2), 169–170). At the Zlatoust plant in the Urals material for cold drawing with a diameter up to 1 in. is drawn through hard metal dies but rods of greater diameter are drawn through steel dies. Some notes are given on the manufacture of various types of steel dies and details of the compositions of the steels and their heat treatment are given.—R. S.

Greater Flexibility for Wire Drawing. M. A. Nye and R. C. Suttle. (*Iron Steel Eng.*, 1957, **34**, Dec., 99–106). The paper discusses recent developments in wire drawing techniques, particularly in the field of electric drives and control gear.—M. D. J. B.

Stable Lubricants on the Base of Mersols and Synthetic Fatty Acids for Steel Wire Drawing. J. Rosochowicz. (*Prace Inst. Mech.*, 1956, **5**, (16), 50–53). [In Polish]. Theoretical introduction and discussion of the problem of applying a lubricant obtained from synthetic fatty acids or Mersols is given. Investigations were carried out on mersolates of Na, Ca, Zn, Al, and on Na, Ca, Zn and Al salts of synthetic fatty acids. Application of these lubricants to steel wire-drawing reduces the drawing force.

Investigations of Wire Flattening. F. Tychowski and H. Olszewski. (*Prace Inst. Mech.*, 1956, **6**, (18), 29–40). [In Polish]. A survey of research in this field up to the present and a description of the author's investigations is given. Mild steel and H. C. copper rods of 5·9 to 16 mm gauge were flattened by drawing. Data of strain and drawing forces are given. From experimental results some coefficients were calculated, allowing an easy computation of the wire gauge necessary in the manufacture of strip. The use of nomographs is discussed.

Extrusion of Metals. F. Tychowski. (*Prace Inst. Mech.*, 1954, **4**, (13), 21–52). [In Polish]. A critical survey of extrusion methods is given. Formulæ for calculating the pressure in different types of extrusion are derived and discussed. Machines and dies for hot and cold extrusion are described. Lubricants used in the extrusion and phosphate coatings are reviewed.

Determination of Durability of Hot-Extruding Tools for Steel. E. Zmirowski. (*Prace Inst. Mech.*, 1957, **6**, (20), 38–52). [In Polish]. The author analyses the conditions of work of tools used in the hot pressing of steel, and gives some reasons for their deterioration. He investigates the influence of high temperatures, of hardening, carburizing and of fast alternating changes of temperatures on the hardness and structure of the following types of steel:
NZ3—0·55%C, 0·9%Si, 1·0%Cr 2%W,
35HGSA—0·35%C, 1·2%Si, 1·0%Mn, 1·3%Cr,
ARA—0·40%C, 1·5%Cr, 0·3%Mo, 1·1%Al,
WNL—0·55%C, 0·7%Mn, 0·7%Cr, 1·5%Ni, 0·4%Mo.

ROLLING MILL PRACTICE

Rolling Mill Building for S.A. d' Espérance-Longdoz at Jemeppe-sur-Meuse (Belgium). A. Henry and L. Warolus. (*Acier Stahl Steel*, 1958, **23**, Jan., 27–30). The steelwork of the shed is described.

The Welding Up of Flakes in Alloy Steel During Rolling. I. N. Golikov and B. M. Litvinov. (*Stal'*, 1958, (1), 67–70). Longitudinal flakes or portions of flakes weld up with slight deformation. Transverse portions open up to form streaks. With deformation, these streaks elongate until the longitudinal walls join together and weld up. Transverse flakes up to 25 mm in a square billet of 125–140 mm weld up in rolling down to 40 × 40 mm bar. The minimum coefficient of stretching needed for welding up such flakes is thus 10–12.—R. S.

The Effect of Rolling Speed on the Mean Specific Roll Pressure, Spread and Elongation in Hot Rolling. Y. Toda. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 923–925).—K. E. J.

Production of Hardened Rolls by Two-Stage Pouring. R. Kamenský. (*Slévárenství*, 1957, **5**, (12), 359–364). [In Czech]. The technology of two-stage casting as developed in the Klement Gottwald Steelworks in Vítkovice is described. The outer layer is cast first and allowed to solidify. The core of the roll is then cast by the use of the same type of cast iron as the surface layer, but ground ferrosilicon is added continuously to the metal stream to ensure a soft ductile core. The method is recommended, particularly for smaller rolls where there is a danger that heterogeneities in composition and hardenability may lead to too great a depth of hardening with consequent embrittlement.—P. F.

Casting Steel Rolls. V. N. Saveiko and M. V. Frolova. (*Stal'*, 1958, (2), 179–184). Production and technical literature data confirm the possibility of successfully exploiting cast steel rolls instead of forged rolls in all the stands of a hot rolling mill, including the cogging mill. The cast rolls must be chill cast. Such rolls have been used in cogging mills for diameters up to 36 in.—R. S.

Calculations of Force and Condition of Rotation of Rolls in Drawing on the Roll Die. F. Tychowski. (*Prace Inst. Mech.*, 1956, **6**, (18), 41–52). [In Polish]. The advantages of the use of the roll-die in the production of strip by the flattening of wire are discussed. Calculation of forces occurring in this process are given. A description of methods used by the author in his investigations and a critical survey of results obtained are reported. The paper presents fundamentals to the technological calculations of the process of wire flattening on the roll-die.

Studies on the Blooming Mill of the Kawasaki Works. K. Kato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 917–919).—K. E. J.

A Modern Rod and Merchant Mill. W. R. Potts and R. M. Lang. (*Iron Steel Eng.*, 1957, **34**, Dec., 161–172). A detailed description is given of the new rod and bar mill at The Atlantic Steel Co. The layout features, electricity, services, the mills, the reheating furnaces and operational techniques are reviewed.—M. D. J. B.

Double-duo Bar Mill Opened in Sheffield. Sanderson Bros. and Newbould Ltd. (*Met. Treatment*, 1958, **25**, Feb., 73, 72).

Experiments to Improve Pass Design for Rolling Flats. G. K. Eremin. (*Metallurg*, 1958, (2), 20–21). An improved pass design is described for rolling 20 × 10 mm, 22 × 10 mm and 22 × 13 mm flats.—R. S.

Flat Rolled Electrical Steel. (*A.I.S.I. Steel Prod. Man.*, 1958, Jan., pp. 39). Magnetic aspects, manufacture by hot mill pack, continuous rolling and rolling effects on directional properties, standard types, and finishing by annealing, deoxidizing, pickling, temper rolling, blueing, oiling, core plating and insulation with organic or inorganic agents are reviewed. Testing is outlined and tolerances are given.

Rational Pass Design in a 280 mm [12 in.] Mill. I. M. Kochetov and V. F. Agarkov. (*Metallurg*, 1958, (2), 22–23). An improved pass design is described for rolling angles and channels. Mill output was raised 15 to 20%, three rollers per shift were freed for other work, power was saved, quality improved and roll life was prolonged.—R. S.

Casting Steel Rolls for Blooming Mills. R. Hroch and A. Koval. (**Slévárenství*, 1957, **5**, (6), 161–168). [In Czech]. The requirements and standard specifications relating to blooming mill rolls are discussed, and an account is given of experiences with the use of cast rolls made of plain 0·4% C steel. The life of such rolls compared favourably with low-alloy steel rolls supplied during the war by a German firm. More recent work is considered and, on the basis of this, it is recommended that (*a*) the roll body and the roll neck should be cast in a permanent mould, (*b*) the head of the mould should be heated by means of an arc or exothermically, (*c*) a cooling bar should be placed in the centre of the mould, (*d*) the permanent mould should be placed on a pad with a guide for the cooling bar, (*e*) the roll should be cast directly by means of an intermediate ladle, (*f*) low alloy Cr–V steel should be used, and (*g*) the addition of Ti should be considered.—P. F.

Study on Charcoal Pig Iron for Chilled Iron Rolls. II. Thermal Properties. K. Otani. (*Tetsu to Hagane*, 1957, **43**, May, 522–527). [In Japanese]. Differences between charcoal iron and normal pig irons were found in respect of the anomalous specific heat value, thermal radiation properties and thermal conductivity. Results are also given for heating and cooling behaviour, transformation temperatures, and specific heat.—K. E. J.

Weld-Surfacing of Rolling-Mill Rolls. M. Mosný. (*Zváranie*, 1957, **6**, (19), 280–285). [In Slovak]. A survey is made of the principles and problems as well as of the economic aspects of roll weld-surfacing.—P. F.

Bearings and Their Lubrication in Rolling Mills. W. F. Griese. (*Stahl u. Eisen*, 1957, **77**, Sept. 5, 1247–1252). This is a comprehensive and critical review of published information on theory and design of bearings and their lubrication.—T. G.

New Synthetic Resin Improves Mill Performance. (*Iron Steel*, 1957, **30**, Oct., 492). The United Coke and Chemicals Co. Ltd., have begun full-scale production of "Orkot" bearings. These make use of a new reinforced synthetic resin which makes it possible in certain cases to double the life of bearings in steel rolling mills.—G. F.

Present State of the Development of Ball and Roller Bearings for Rolling Mills. G. Strafe. (*Stahl u. Eisen*, 1957, **77**, Sept. 19, 1315–1329). A comprehensive review of ball and roller bearings used in rolling mills, discussing the various design principles for meeting the individual requirements of different types of mills.—T. G.

Results of Works Studies of Blooming Mills. I.—Methods for Measuring the Characteristic Data in Rolling. H. G. Müller and H. J. Marx. (**Stahl u. Eisen*, 1957, **77**, Oct. 31, 1577–1582; discussion, 1605–1607). The authors deal with the measurement of rolling force, torque, power required, etc. The measuring techniques are described in detail. **II.—The Rolling Forces.** H. G. Müller and W. Lucg. (1583–1593; discussion, 1605–1607). The authors measured the torque at the upper and lower rolls and found large differences between the two. They discuss vibration of the driving spindles and its effect on operation, force and torque. The effect of evenly and unevenly heated ingots on rolling force was examined. The results obtained are discussed in detail with respect to improvement of the operation of the rolling procedure. **III.—Load and Action of Electric Drives.** W. Nürnberg. (1593–1607). The variation of the rotor current during normal rolling operations was measured together with rise in temperature of the winding. The results are presented in many graphs and tables. The author suggests improvements in the design and construction of electric drives for reversing mills.—T. G.

Control Gear and Speed Control of the Twin-Drive of a Slab Mill. O. Martin. (*Stahl u. Eisen*, 1957, **77**, Oct. 31, 1607–1610). The author describes the twin drive of a 4·2-m slab mill at Hattingen, where one-anode rectifiers in duplex-parallel connection are used. The advantages of this type of drive in particular in connection with one-anode rectifier vessels are stressed. Operation of this type of drive requires highly skilled personnel and permanent supervision is even then necessary.

The Cooling of Rolled Products Which Are Prone to Hydrogen Flake Formation. D. A. Litvinenko, V. V. Turitsyn, and P. N. Poryshkov. (*Metallurg*, 1957, (7), 23–24). Blooms from the 46-in. cogging mill at the Red October plant in Stalingrad are slowly cooled on a 2-in. thick layer of sand (at 6 to 12° C per h). Below 400° C, cooling is retarded and in summer the tempo of rolling is slowed down by this "bottle neck." Recent cooling trials have evolved a new 48-h cooling method instead of the former 72-h period.—R. S.

The Rolling of EI437A Heat-Resisting Alloy. I. P. Zabaluev, V. I. Travinin, and M. A. Kovaleva. (*Stal'*, 1957, (10), 919–923).

The Causes of Wrinkle Formation on Round Sections during Rolling on a Heavy Section Mill. S. Z. Yudovich and M. S. Kanev. (*Stal'*, 1957, (10), 924–928). Proper roll design eliminates wrinkling and also reduces the amount of rolled-in scale.

Improving the Quality of Hollow Drill Steel. A. S. Byelousov and P. P. Kon'shin, C. Z. Kantor, V. D. Semkov, P. N. Sporyshkov, V. V. Turitsyn, and Yu. M. Chizhikov. (*Metallurg*, 1957, (2), 21–27). Experience of good and bad roll pass design for producing hollow drill steel at several plants is reported.

The New Light-Section and Wire-Rod Mill of Klöckner-Hüttenwerk Haspe at Hagen-Haspe. A. Weyel and H. Weide. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1464–1476). The new mill completed in 1956 has a total of 24 stands and a throughput of 25,000 t per month. The mill, its layout, the auxiliary equipment, operation, etc. are described in detail.—T. G.

Modern Rod Mills. O. Wilmes. (*Draht*, 1957, **8**, Oct., 425–428). Surveying recent developments, the author states that narrow dimensional tolerances demanded in Europe (± 0·004 in.) make single strand finishing desirable, with individually driven stands so as to avoid interstand tension; likewise twisting should be avoided by alternating horizontal and vertical stands. He then describes in detail the ARBED narrow strip and rod mill built by DEMAG.—J. G. W.

The New Continuous Wire Rolling Mill of Niederrheinische Hütte A.G., Duisburg, Germany. (*Wire*, 1957, Aug., 31–32). This rod mill, commissioned in 1955, reached 80% within two months from installation, has a finishing speed of 5600 ft/min for 0·196 in. rod. Ultimately it is to be a four-strand, fully continuous mill with individually driven, alternately horizontal and vertical finishing stands, with an annual output of 360,000 t. Some details of this mill and of changes in blooming and billet mills are quoted.—J. G. W.

Combined Hot Rolling and Patenting of Rod. D. Lewis. (*Wire Wire Prod.*, 1957, **32**, Oct., 1179–1182, 1262–1264). A brief historical introduction and description of the process is followed by an account of the installation with details of various devices in the live and temperature records.

The Continuous Wire-Mill of the Société Métallurgique de Normandie. G. Leder. (L. Boulez). (*Stahl u. Eisen*, 1957, **77**, Oct. 31, 1624–1625; from *Techn. moderne*, 1957, **49**, (7), 354). The mill at Mondeville was completed in 1951. It has 19 stands and uses 52- or 70-mm-square bars, which are reduced to 5–12 mm dia. Throughput per h using 52-mm-square bars is 45 t. The small number of stands requires relatively high reductions per pass, markedly higher than in most modern wire-rod mills.—T. G.

Production of Railway Rails. A. A. Slinko. (*Metallurg*, 1957, (8), 41–43). The studies of an Inter-Works School on Rail Production based on work at Kuznetsk, Novo Tagil, and Azovstal are reviewed. Heat treatment, rail pass design, roll quality, straightening and some rail defects are discussed. Some recommendations are made for improving rail production in the U.S.S.R.—R. S.

The Production of Sheet for Deep-Drawing for the Automobile Industry. G. D. Rogoza. (*Stal'*, 1957, (10), 941–943). To increase ingot weight, which may make inhomogeneous rimming steel with inferior drawing properties, non-ageing killed steels were substituted, with sheet hardness control.

Experience in the Building and Operation of the Sheet Rolling Mill 2400. I. Arzenšek. (*Nova Proizv.*, 1954, **5**, (3–4), 200–206).

Production of Hot-Rolled Plates from X18H25C2 Steel. V. A. Filonov, F. A. Ksenzuk, V. N. Lola, and A. L. Khudas. (*Stal'*, 1957, (10), 917–918). Rolling of 10¼-t ingots is described. In a continuous mill the temperature should be as high as possible.

Mechanization of Thin Sheet Rolling. O. Ciril. (*Nova Proizv.*, 1954, **5**, (3–4), 240–248). An account of the mechanization of a Yugoslav rolling mill with increase of production of 20% is given.

The Thick Sheet Steel Mill "2800." I. A. Revin. (*Vestnik Mashinostroenniya*, 1957, (4), 28–33). [In Russian]. This is a description, with photographs, of the sheet mill installed in 1955 in the Urals Machine Plant. Below are some indications of its capacity and size: Thickness from 4 to 50 mm, width from 1000 to 2500 mm, and length from 2500 to 18·000 mm, from billets of from 100 to 250 mm thickness, 700 to 1550 mm width, and 1500 to 5500 mm length, weighing up to 7500 kg. The mechanical installation includes 85 separate machines and mechanisms weighing ~ 14,000 t on an area of 42,966 m². A full description is given in the text.—L. H.

Making Better Steel Sheet: Metal Behavior During Cold Rolling and Aging. H. C. Rogers. (*J. Met.*, 1957, **9**, Aug., 1034–1039). The author discusses the correlation between the effects of mechanical working and modern theories of dislocation and strain ageing, giving an insight into the design and practical use of cold rolling facilities. (59 references).—G. F.

Hot Rolled Carbon Steel Strip. (*A.I.S.I. Steel Prod. Man.*, 1957, Oct., pp. 26). A revision of the March 1955 issue.

Cold Rolled Carbon Steel Strip. (*A.I.S.I. Steel Prod. Man.*, 1957, Oct., pp. 27). A revision of Feb. 1955 issue.

Automation in Strip Rolling. Control Systems in a New French Mill. M. G. Liégeois. (*Iron Coal Trades Rev.*, 1957, **175**, Nov. 22, 1205–1209; from *Technique Moderne*, 1957, **49** July, 370–374). Charging by roller convoyor, the three-zone pusher Stein-Rust type furnace, where air flow is controlled in the preheating zone and oil flow in the heating and equalizing zones, also the safety devices, the scale breaker, roughing train, finishing train and flying shear, loop tensioners and coilers are all briefly described. The mill is at the Rehon Works, S.A. des Usines de la Providence.

The Effects of High Strain Rate in Strip Rolling. D. G. Christopherson and B. Parsons. (*Sheet Met. Ind.*, 1957, **34**, Oct., 769–775). An experimental mill is described and measurements of thickness and width, drawing force, roll force, back tension, friction in bearings, static mechanical properties, and hardness of strip were made. Mild steel and non-ferrous metals were tested. Frictional effects are estimated in an appendix.

Specifications for the Design of a "250" Finishing Mill Alley. C. Ryšánek. (*Hutn. Listy*, 1957, **12**, (10), 881–883). [In Czech]. Principles underlying the rational design of the mill are discussed.—P. F.

The Cold Rolling of Extra-Hard Carbon Steel and Its Influence on Heat Treatments Involving Quenching. M. Massin. (*Sheet Metal Ind.*, 1957, **34**, Nov., 847–857; Dec., 929–940). Cold rolling mills and their operation are sketched and measurements of latent energy in work-hardening are reported. Thermal analyses were carried out on specimens after a variety of treatments and variations of internal energy in cold-rolling determined, the α–γ transformation was included in the study, also work hardening. Microstructures after cold-rolling and their restoration by heat treatment were examined and back-reflexion X-ray patterns are shown. A review of mechanical properties of hardened and tempered steel strip and energy release in relation to the transformation points is then given. It is concluded that the heat release is characteristic of the material but the factors determining the temperature at which this takes place have not been identified.

Deformability of Transformer Sheet in Cold Rolling. G. N. Shubin, V. H. Shadran, and N. I. Lapkin. (*Fiz. Met.*, 1955, **1**, (1), 180–184). Reductions up to 40% per pass can be produced in steel with 3–4% Si. This raises the temperature to 150–200° C and facilitates rolling. Preliminary annealing not above 750–800° C (or 800–850° *in vacuo*) assists. The results can be used to estimate power requirements.

Methods of Minimizing Edge Cracks [In the Rolling of Transformer Sheet]. N. F. Dubrov. (*Metallurg*, 1956, **1**, (12), 23–24). High-Si sheet with 0·2–0·25% Al was rolled and the effects of lowered S and increased Mn and of rolling at lower temperatures were noted. These measures reduced discards owing to edge cracks from 4·56 to 0·40%.

Production of Cold Rolled Transformer Steel. A. I. Belyakov. (*Metallurg*, 1957, (5), 22–24). The first Russian cold rolled transformer sheet 0·35 to 0·50 mm thick was rolled in 1949. The use of Si–Ca instead of Al and Fe–Si for deoxidation improved the electromagnetic properties. Details of heat treatment and composition are given.—R. S.

Threading by Means of Plastic Deformation. (*Tecn. Indust.*, 1957, **35**, Apr., 389–391). [In Spanish]. The advantages and principles of producing threads by cold rolling methods are described. Machines for this purpose are discussed.—F. S.

Tube Mill Production in the U.S.S.R. Yu. M. Matveev. (**Stal'*, 1957, (11), 997–1005). A review of the past 40 years with statistics, plans, and illustrations.

Influence of Billet Defects on the Quality of Tubes. S. I. Orlov. (*Metallurg*, 1957, (5), 26–29). Details of many tube casts are given. The main trouble was internal porosity and non-metallic inclusions, particularly at Novo-Tagil (Urals).—R. S.

Rapid Changeover of Steel Mill Drive. (*Can. Metalw.*, 1957, **20**, Sept., 26). Piecemeal installation of electrical equipment, including magnetic amplifier controls, without major interruption at Dominion Foundries and Steel Ltd. is outlined.

Surface Defects in Sheets. A. S. Babii and G. Z. Shcherbina. (*Metallurg*, 1957, (9), 21–23). The article deals with defects such as segregation, sand patches, slag inclusions and the effect of sheet thickness and of the method of heating the ingots on the surface quality of the finished sheets.—R. S.

Power for Steel Production: Electrical Equipment for a Cold Cut-Up Line. (*Elect. Rev.*, 1957, **161**, Sept. 13, 469–472). A description of the Steel Co. of Wales installation at the Abbey works is given.

Problems in Bending Plates. (*Tecn. Indust.*, 1957, **36**, July, 811–814). [In Spanish]. The author points out that the bending process to produce cylindrical shapes is very often thought to be of little importance with the result that quality is poor and accuracy is low. The disadvantages of the older pyramid rollers are discussed with reference to the improvements obtainable by asymmetric 3-roll or 4-roll machines.—F. S.

Reboring of Mill Machinery Parts at Site. N. P. Naik. (*Tisco*, 1957, **4**, Oct., 199–203). The author discusses the factors affecting the design and fabrication of a boring jig and then shows the correlation between the shop floor trials and the actual use in the field. Two typical reboring jobs are used as illustrations.

The Accuracy of Strip-Thickness Measurement by Beta and Gamma Absorption. E. B. Bell. (*J. Inst. Met.*, 1958, **86**, Mar., 303–307). A mathematical investigation.

Measurement, Inspection and Automatic Process Control in the Steel-Strip Finishing and Tinplate Industry. S. S. Carlisle and J. H. Wilson. (*J. Inst. Met.*, 1958, **86**, Mar., 310–315). Continuous non-destructive inspection and measuring techniques are reviewed and the need for a method of measuring surface quality is noted. Developments in technology may eliminate the need for automatic quality control and the study of instrumentation should be integrated with research into process technology.

MACHINERY AND SERVICES FOR IRON AND STEEL PLANT

Specification for Geared Steelfoundry Ladles. (*Found. Trade J.*, 1958, **104**, Mar. 27, 347–349). Ladles up to 10-t capacity in squat and tall designs are included in a specification drawn up by the British Steel Castings Research Association.

Hermetic Sealing of Scale Car Cabs. A. A. Krivosheev and A. G. Geiko. (*Metallurg*, 1958, (21), 7–8). The use of hot sinter at 400–450° C made conditions in scale car cabs at the Dzerzhinsk plant unbearable. Nine hermetically sealed cabs were installed, using 3 mm thick steel sheet. All controls are inside the cabin. Air conditioning plant is described.

Britain's First Steelworks Gas-Turbo-Alternator Set. Richardson Westgarth Ltd. (*Oil Eng. Gas Turb.*, 1958, **25**, Mid-Feb., 391, 393).

LUBRICATION

Choose the Right Lubricant. L. Salz. (*Steel*, 1957, **141**, Oct. 14, 132, 134, 135; Oct. 21, 100–101). Lubricants for drawing are reviewed. General properties are given and a brief guide to the water-dispersible and oil types is added. In part 2 the latter are classified into pressure, chlorine and sulphur types, and spacers, emulsifiers, diluents, inhibitors and chemical coatings (phosphate or oxalate) are indicated in general terms.

Lithium-Based Grease Reduces Blast Furnace Lubrication Costs. (*Iron Steel Eng.*, 1957, **34**, Oct., 162–163). The specification of a typical lithium grease is given and its advantages in blast furnace maintenance are discussed.—M. D. J. B.

Current Status of Spindle Slipper Lubrication. W. G. Ritter. (*Iron Steel Eng.*, 1957, **34**, Dec., 152–156). A method of lubricating rolling mill spindle slippers is described which, it is claimed, reduces wear and considerably increases spindle life.—M. D. J. B.

The Mechanism of Boundary Lubrication and the Properties of the Lubricating Film. Short- and Long-Range Action in the Theory of Boundary Lubrication. B. V. Deryaguin, V. V. Karasev, N. N. Zakhavaeva and V. P. Lazarev. (*Wear*, 1957–58, **1**, Feb., 277–290).

Case for Molybdenum Disulphide. H. Simon. (*Steel*, 1957, **141**, Dec. 30, 68–69). Examples of MoS_2 providing lubrication unobtainable by other materials is given. Several instances are of close-fit assembly; heavily loaded conveyor tables have also been treated with success.—D. L. C. P.

The Extreme-Pressure Lubricating Properties of Some Sulphides and Disulphides, in Mineral Oil, as Assessed by the Four-Ball Machine. W. Davey and E. D. Edwards. (*Wear*, 1957–58, **1**, Feb. 291–304). Mechanism of action of (organic) sulphides is discussed.

WELDING AND FLAME CUTTING

Development of Welding Techniques in Czechoslovakia. N. N. Rykalin. (*Izvest. Akad. Nauk Otdel. Tekhn.*, 1957, (9), 101–107). [In Russian]. The author describes welding research centres in Czechoslovakia and outlines proceedings at the VI International Welding Conference held at Smolenitsa in September, 1956.—S. K.

Science and Technique of Welding in the Soviet Union. N. N. Rykalin. (*Brit. Weld. J.*, 1957, **4**, Dec., 541–547). A lecture. Automatic arc, electro-slag and gas-shielded arc methods are described.

New Techniques Solve Welding and Brazing Problems with PH Steels. F. K. Lampson. (*S.A.E.J.*, 1957, **65**, Dec., 37–39). Cracked welds and low ductility, oxidation of Al, crevice corrosion and defective bonding are discussed.

Butt Welding Austenitic Stainless Steel to Ferritic Steel in Cylindrical Shapes. J. E. Donahue. (*Welding J.*, 1957, **36**, Nov., 1074–1077). The design and manufacture of transition pieces between austenitic and ferritic steels for a central power station steam turbine is described. The transition pieces are formed by a carefully controlled butt weld.—U. E.

Welding High-Tensile Steels. K. L. Zeyen and H. Schwarz. (*Welding J.*, 1957, **36**, Nov., 480s–482s). Physical properties are given for several types of high-tensile steels together with their compositions.—U. E.

Tips on Welding Stainless. H. F. Reid jun. (*Iron Age*, 1957, **180**, Dec. 26, 58–60). Martensitic, ferritic and austenitic types and their welding properties are briefly surveyed with special reference to carbide precipitation and its prevention, and choice of electrode is indicated.

A New CO_2 Welding Process. A. F. Chouinard and R. P. Monroe. (*Welding J.*, 1957, **36**, Nov., 1069–1073). A new CO_2 semi-automatic and automatic welding process for mild steel is described. Current used is D.C., reverse polarity supplied by a constant potential type of rectifier welding machine and the electrode a flux-cored one. Metal deposition is speeded up and physical properties are equal to or higher than E6012 values.—U. E.

Inert Gas Tungsten-Arc Spot Welding of an Automotive Transmission Subassembly. W. G. Mertens and O. J. Ryder. (*Welding J.*, 1957, **36**, Sept., 871–876). A spot welding machine is described which produces a multiple array of spot welds.—U. E.

Thick Plate Welding for Nuclear Energy Applications. (*Welder*, 1957, **26**, July-Sept., 66–71). The welding of thick plate for a reactor pressure vessel is described in detail.

Boiler-Code Welding and Joint Design with the CO_2 Process. J. D. Carey jun. (*Welding J.*, 1957, **36**, Sept., 877–880). The CO_2 gas-shielded process was applied to the welding of two grades of boiler code steels, A285 grade C and A212 grade B. It is shown that the boiler code steels have the same degree of weldability as other mild steels.—U. E.

The Welding of Type 347 Steels. A. Hoerl, T. J. Moore. (*Welding J.*, 1957, **36**, Oct., 442s–448s). A sensitive segmented circular-groove cracking test was used for examining fully austenitic 347 steel welded with a CaO coated electrode. C and Mn were found to be the most potent elements in reducing cracking and P and S in producing cracks.—U. E.

Inert Gas Tungsten-Arc Welding SAE 4130 Steel Sheet—2. C. A. Terry and W. T. Tyler. (*Welding Metal Fab.*, 1957, **25**, Nov., 442–448). Factors affecting weld cracking in tungsten-arc welded low-alloy steel SAE 4130 have been investigated. The incidence of transverse cracks occurring in SAE4130 welds is shown to be related to microstructural features, pearlite/ferrite banding having a deleterious effect. It is found that the cracks are not associated with metallurgical changes which occur at temperatures below the upper critical temperature of the steel.—U. E.

Welding Problems in Pressure Vessels for Nuclear Reactors. R. E. Lorentz jun. (*Welding J.*, 1957, **36**, Sept., 881–887). The fabrication of pressure vessels for nuclear reactors is described. Data are given of impact properties of manual metal-arc and multi-layer submerged-arc welds. Non-destructive testing methods are briefly discussed.—U. E.

Weld Repair of a Heavy Press Column. (*Can. Metalw.*, 1957, **20**, Dec., 30). The fracture of the column of a 2000-t hydraulic press was restored within a week by the process briefly described.

A Remarkable Welded Repair to a 3000 ton Press. (*Welder*, 1957, **26**, July-Sept., 76–80). A 3000-t Somua lead extruding press was repaired by welding. A large crack was drilled out and preheating was carried out before proceeding with the multilayer welding method.—U. E.

Shielding Gases for Inert-Gas Welding. W. H. Helmbrecht and G. W. Oyler. (*Welding J.*, 1957, **36**, Oct., 969–979). Recent developments in inert-gas-shielded arc welding are reviewed. Arc characteristics, flow rate and weld quality obtained with each gas or gas mixture have been summarized for each metal and for each inert-gas process. Argon has proved to be universally the best shielding gas.—U. E.

On the Weldability of Electric Resistance Welding Pipe. S. Hasebe. (*Tetsu to Hagane*, 1955, **41**, Sept., 1053–1056). [In Japanese.]

"Squirt Gun" Welds Dissimilar Metals. A. R. Kemerer. (*Metalw. Prod.*, 1957, **101**, Dec. 13, 2220–2221). The joining of steel to $\frac{1}{8}$ in. stainless by a semi-automatic submerged-arc technique using 18–8 stainless wire and a chrome-rich flux is described.

Friction Welding. J. Mandaus and J. Viboril. (*Eng. Digest*, 1957, **18**, Nov., 490–491; from *Strojirenství*, 1957, (9), 681–686; abridged, with 5 of 35 illustrations). Welds of C steel to low-alloy Cr–Mo steel are shown produced by rotating one part against the other held stationary and applying pressure.

Bonded Fluxes for Submerged-arc Welding of Alloy Steels. H. C. Campbell and W. C. Johnson. (*Welding J.*, 1957, **36**, Nov., 1078–1084). A new type of submerged-arc welding flux is described. In the flux are incorporated alloying elements, deoxidizers, and strong fluxing agents; a different colour will distinguish those for use for either stainless steel or low alloy steel.—U. E.

Selection of Welding-Rod Chemical Composition Through Mathematics. G. H. Bohn. (*Weld. J.*, 1957, **36**, Dec., 541s–549s). A Cu–Si–Mn–Fe composition is worked out from a formula giving minimum tensile strength of weld as a function of Si, Mn and Fe contents. Revisions in specifications are suggested.

A New Nodular Cast-Iron Welding Rod for Foundries and Fabricators. R. O. Day, J. S. Snyder and H. V. Inskeep. (*Welding J.*, 1957, **36**, Sept., 410s–414s). Data are presented for a nodular-iron welding rod used for oxy-acetylene welding giving a weld metal bead of a fully nodular ferritic iron structure. Mechanical properties are given.—U. E.

Materials Testing in Welding. M. Pfender. (*Schweisstechn.*, 1957, **11**, Nov., 121–136). A lecture delivered at the welding symposium held at Böhler Kapfenberg, Austria, on 6-8 Sept., 1956, in commemoration of the 25th anniversary of the welding training and research institute of Böhler. The author deals with the conventional testing methods describing them in detail, but he also gives the causes for the various defects in the welds that should be found by the testing methods. (36 references).—T. G.

Stress Relief of Mild-Steel Welded Structures. S. J. Watson. (*Brit. Welding J.*, 1957, **4**, Sept., 422–423). Tensile-relaxation tests have been carried out at temperatures from 500° to 650° C. It was found that the residual stress after 1 h heating at 600° C was 2·5 tons/in² and after 6 h heating at 650° C was 0·5 tons/in². The effect of annealing time is shown to be much less important than the annealing temperature.—U. E.

Economies in Boiler Steel Consumption by Increasing the Coefficient of Weld Quality. R. Krňák. (*Strojírenství*, 1957, **7**, (12), 921–924). [In Czech]. Methods for assuring high-quality welds in the construction of locomotive and other all-welded boilers are discussed, and the possibilities of saving boiler steel, arising from improved weld quality, are considered.—F. F.

Ferritic-Austenitic Weld Joints in Thermal Power Stations. F. Zimmer. (*Eng. Dig.*, 1958, **19**, Mar., 99–102, from *Revue Met.*, 1957, **3**, Oct., 162–174). A review of welds and other types of joint, with screw, flanged and powder metal transitional fittings.

Problems Arising in Automatic Submerged Arc Welding of Low Alloy Steels. J. Zeke. (*Zváranie*, 1958, **7**, (1), 2–8). [In Slovak]. The various lines of development of automatic welding of low alloy steels are surveyed, and their respective scopes and advantages are assessed. The construction, function and uses of various filler rods or tubes and of fluxes are considered from the theoretical and practical points of view, with special reference to methods favoured in the U.S.S.R.

Tasks in the Automatic Submerged Arc-Welding of Low-Alloy Steels. J. Zeke (*Zváranie*, 1958, **7**, (2), 54–56). [In Slovak]. The development and testing of a new flux is described. The flux, which was found to be satisfactory in practice, had the composition: 23%SiO_2, 24%MnO, 25%Al_2O_3, 6%CaF_2, 18%CaO, 1%MgO, 2%Fe_2O_3 and 1%K_2O.

The Arcair Process. G. Doneux. (*Prut. Soud.*, 1957, **11**, June-July, 95–102). [In French]. The Arcair process is a gouging process which enables metal to be removed from all types of steels including carbon, stainless and 14% Mn austenitic steels and from non-ferrous metals. The process consists in melting the metal by an electric arc struck with a special graphite electrode operating in a stream of compressed air.—M. D. J. B.

Projection Welding of 24 s.w.g. Mild Steel. J. E. Roberts and G. A. Phipps. (*Brit. Weld. J.*, 1957, **4**, Dec., 557–563). Optimum conditions for single, double and triple projection welds were found by determination of mean strength, consistency and surface appearance. Two steels were also compared (with single welds) and the steel with inferior mechanical properties produced lower-strength welds. Deep-drawing O.H. sheets were used with 0·06 and 0·065% C.

Welding of Heat-Resisting Steels. H. H. Weigand. (*Schweissen Schneiden*, 1958, **10**, Feb., 44–49). The arc welding of heat-resisting austenitic steel is investigated. The effect of alloying elements on the quality of the weld is determined. It is shown that small amounts of ferrite in weld metal in 18/8 stainless steel will prevent hot cracking.—U. E.

The Application of the Oxygen Lance with Steel Wire and Flux Powder. H. Jansen. (*Schweissen Schneiden*, 1958, **10**, Jan., 20–26). The application of the two types of oxygen lances is decribed. The oxygen lance with a steel wire is used for boring steel and stone, and the powder is used for cutting operations. The economics of both applications are discussed.—U. E.

Filler Metals for Braze Welding. International Institute of Welding. (*Brit. Weld. J.*, 1957, **4**, Dec., 553–555). Specifications for determining the characteristics of the deposited metal (by tensile test) and for determining the strength of the bond on steel, cast iron and other metals are given.

How to Braze Stainless Steels. H. M. Webber. (*Ind. Heat.*, 1958, **25**, Feb., 247, 248, 250, 252, 254, 400, 402; Mar., 503–504, 506, 508, 510, 512, 514; Apr., 708, 710, 714). A brief discussion of base metals, filler metals, wetting action, and selection of equipment is given.

MACHINING AND MACHINABILITY

Investigations of the Machinability of Structural Steel by the Thermoelectrolytic Method. L. Kops. (*Prace Inst. Mech.*, 1956, **5**, (17), 34–43). [In Polish]. The author discusses the application of thermoelectrolytic methods of machining of some machine components. He describes in detail his investigations of machinability of constructional steel (45 hardened). The results are shown with graphs and photographic illustrations and are critically analysed.

Control of Chip Form While Turning. E. Bickel. (*Mircotecnic*, 1957, **11**, Dec., 253–255). Chip forms are classified and the use of a chip breaker investigated.

Concentrated Wear of Turning Tools. V. Šolaja. (*Research*, 1958, **11**, Apr., 152–156). An examination of grooving of the clearance face of tools and an attempt to explain the phenomenon are recorded. Abrasive and corrosive wear processes are considered and also fatigue effects. (24 refs.).

Features of the Cutting Operation, and Efficient Arrangements for Cutting Steel with Tools from High-Melting-Point Alloys. G. L. Khaet. (*Vestnik Mashin.*, 1958, (1), 77–83). The introduction of cutting tools, of specially calculated shapes, made from high melting point alloys, has increased the efficiency of labour between three and five times and made possible the processing of materials otherwise difficult to cut. The suggestions made as a result of these extensive tests have been confirmed by actual practice.—L. H.

Calculation of the Force for Cutting Sulphur Iron when Turning and Milling. Yu. A. Rosenberg and L. M. Sedokov. (*Vestnik Mashin.*, 1957, (12), 68–71). The process of cutting sulphur iron is a brittle deformation with simple displacement. The tangential stresses to the plane of displacement depend only on the hardness of the material. The calculation of the cutting force required must be considered in relation to the front and back edges of the cutting elements and their different parameters to the cutting operation.

The Cutting of Round Wire with Knife-Edge and Flat-Edge Tools. W. Johnson. (*Appl. Sci. Res.*, 1957, **7A**, (1), 65–88). The basic mechanics of the operation are elucidated, greatest load required, wedge tool angle and other parameters are determined and greatest cutting load and wire diameter are shown to have a log/log relationship. An expression also relates these to wedge angle.

Effect of Structure of Titanium-Tungsten Carbide Compositions Upon the Life of Tool Tips. P. K. Mikhailova. (*Stanki. Inst.*, 1957, **28**, (6), 26).

Shot Peening. H. O. Fuchs and E. R. Hutchinson. (*Mach. Design*, 1958, **30**, Feb. 6, 116–125). The nature of the process, its effects and uses are reviewed, and the designer is advised where it should be specified. Its effect on fatigue life is discussed and the Almen number explained. (23 refs.).

The Wear of Electric Contacts in Electro-erosion Machining. M. Bruns and J. Roncin. (*Wear*, 1957–58, **1**, Feb., 305–316). [In French]. A preliminary study to identify the parameters involved is reported with a discussion of uses and probable extensions of the process.

CLEANING AND PICKLING

Some Aspects of Cleaning Prior to Metal Finishing. B. Whitehead. (*Electropl. Met. Fin.*, 1958, **11**, Feb., 35–42). Types of soil, degree of cleanliness and a general account of cleaning methods are considered. Blasting tumbling, pickling with acids, alkali cleaning, emulsions and fused salts are briefly surveyed and the processes of agitation, especially ultrasonic methods, are reviewed.

Studies on Hot Rolled Scale. T. Watanabe. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 988–989). Pickling results are given in terms of pickle lag for various HCl concentrations, temperatures and inhibitors used.—K. H. J.

The A.R.D.E. Chemical Smoothing Process for Steel. (*Electrop. Met. Fin.*, 1958, **11**, Mar., 82–84). An oxalic acid —H_2O_2—H_2SO_4 mixture is used and is useful for the restoration of rusted articles. A general account of the process is given with illustrations.

Slide-Honing: A New Barrelling Technique. C. Emerson. (*Metalw. Prod.*, 1958, **102**, Mar. 14, 453–455). A precision method confining parts to sliding and rolling is described.

Electropolishing of Steel with Alternating Current. T. Zak and J. Socha. (*Prace Inst. Mech.*, 1956, **5**, (16), 25–31). [In Polish]. The possibilities and theroretical basis of electrolytic polishing of stainless steel with a.c. (50 cycles) are discussed. The experiments conducted by the authors are described and the results obtained shown by graphs. Different results of polishing were obtained with different concentrations of gelatine in H_3PO_4. Epelboin's method is discussed.

PROTECTIVE COATINGS

A New Method for the Precise Evaluation of the Capacity of Plating Installations. D. O. Bartl and O. Mudroch. (*Electropl. Met. Fin.*, 1958, **11**, Feb., 43–46). Equations for the calculation are given taking into account the dimensions and shape of the tanks and of the work and the character of the solution and of the anodes. They apply also to automatic and to semi-automatic plant. The current required can also be obtained.

Barrel Plating. P. Glab and the Chicago Branch of the A.E.S. (*Proc. Ann. Conv. Amer. Electroplaters' Soc.*, 1957, 116–120). Plant and processes are discussed and plating finishes, conversion coatings and other topics are reviewed and future trends indicated.

The Future of Plastics in Electroplating Plant. H. Silman. (*Proc. Ann. Conv. Amer. Electroplaters' Soc.*, 1957, 95–101; discussion 164–165). PVC, polythene polytetrafluoroethylene, nylon, and glass fibre compositions are considered and their uses for tanks, barrels, ducting and pipes evaluated.

Corrosion and Materials of Construction in the Plating Room. T. J. V. Cudbird. (*Proc. Ann. Conv. Amer. Electroplaters' Soc.*, 1957, 91–94; discussion 164). Steels, non-ferrous metals, silicon-iron, rubber and vinyl plastics are considered.

Which Coating at High Temperature. G. D. Oxx, jun. (*Prod. Eng.*, 1958, **29**, Jan. 20, 61–63). Chromium and alumina coating of steel are included in an account of protective measures against oxidation and erosion. Temperature limits are shown and advantages and disadvantages noted.

Stress-Free Nickel Plate. Some Notes on Experience with the Sulphamate Bath in the U.S.A. E. Calderon. (*Met. Fin. J.*, 1957, **3**, Sept., 373–374).

Alloy Coating Gains Momentum. (*Chem. Eng. News*, 1957, **35**, Oct. 14, 68–69). Kanigen plating, containing 9% P is described and its corrosion resistance is said to exceed that of pure Ni.

Galvanization of Strip. J. Landeau. (*Technique Moderne*, 1957, **49**, July, 413–415). The Sendzimir, U.S. Steel Corp., and Wheeling Steel Corp., processes are outlined.

Progress in Galvanising, 1956. (*Proc. 4th Internat. Galvanizing Conf., Milan, Zinc Development Association*, 1957, pp. 232). **A Survey of European Galvanising Practice in 1955.** D. N. Fagg. (3–22; Discussion 22–26). Results of a questionnaire are presented, plant, technique and efficiency are surveyed in 40 plants in Great Britain and Europe. **The Influence of Impurities in Iron on Attack by Molten Zinc.** D. Horstmann. (29–47, Discussion 47–51). Attack on pure iron and effects of C, Si, Mn, P, S, Cu and Al

are considered. The structures of the alloy layers are also shown.

Construction of Galvanizing Pots. L. F. Chambers, G. R. Faulks and W. A. Jenkins. (55–58; Discussion 58–65). **Heating, Performance and Heat Consumption of Galvanizing Baths.** H. Wubbenhorst. (69–82). Fuel and resistance heated iron pots, cover-heated fireproof baths, sensible heat utilization (Sendzimir strip steel process) and induction heating (Ajax process) are reviewed. Choice of fuel, heat balance, circulation systems and design are discussed. **Electrical Resistance Heating for Galvanizing Baths.** R. Gloor. (82–86). Installation and safeguards are outlined. **Galvanizing Bath Heated by Gas Immersion Heaters in Lead Pockets.** L. F. Chambers. A bath of this type is briefly described and its performance given. (Joint Discussion, 88–98). **The Benefits of Applying Work Study to General Galvanizing.** A. G. Norcott. (101–114; Discussion 114–117). **The Galvanizing of Angle Sections.** J. Frieli. (121–130; Discussion 130–132). A study of conditions carried out by two firms is reported. Temperatures and times and the uniformity and adhesion of the coatings formed were examined. **The Galvanizing of Cast Iron.** S. A. Hiscock. (135–165; Discussion 165–170). Examination of commercial samples is reported, structures are shown and conclusions drawn. Costs are surveyed. The effects of the iron composition, structure and quality and the surface finish of castings on coating conditions and results are discussed. **The Galvanizing of Hexagonal Wire Netting.** C. C. Lepage. (173–178; Discussion 178–181). **The Painting of Hot Dip Galvanized Steel.** J. F. H. Van Eijnsbergen. (185–195; Discussion 195–203). Surface pretreatment and paint systems are reviewed. A table of oil and synthetic vehicles is given and suitable pigments are indicated. **New Markets for Galvanizing.** (207–222). Various applications are mentioned and illustrated.

Electrodeposition and Dissolution of Zinc in Zincate Solutions. I. Sanghi and W. F. K. Wynne-Jones. (*Proc. Indian Acad. Sci.*, 1957, **46A**, Oct., 309–321). A study showing the improvement of the deposits from alkaline zincates effected by traces of lead acetate.

Chromate Conversion Coatings on Hot-Dipped Galvanize. C. W. Ostrander. (*Products Fin.*, 1957, **22**, Oct., 60–64, 66, 68, 70, 72). A general account, with some laboratory corrosion test results, is given. A typical installation is briefly outlined and a programme of exposure tests set out.

Improved Formability of Galvanized Sheet. J. R. Kattus. (*Metal Progress*, 1957, **72**, Dec., 82–85, 140). High-speed tensile tests on both smooth and notched specimens show significant differences in properties between acceptable galvanized sheets and those which are susceptible to breakage in fabrication on a "Lockformer" machine. The ultimate strength of notched specimens provides the best measure of performance, increasing strength being indicative of increasing susceptibility to breakage.—G. F.

Beta-Ray Gauge for Measurement of Galvanising Thickness. G. B. Wills. (*Engineer*, 1957, **204**, Dec. 20, 901–902). A back-scatter gauge is described and its accuracy shown against the B.S.S. 443 stripping test.

Recent Tinning Installations for Production of Tin Plate. J. Breuzet. (*Technique Moderne*, 1957, **49**, July, 407–412). A general review of production methods with statistics of production and an account of hot dip and electrolytic processes, and a description of the "Ferrostan" line are given.

The Mechanism of Formation of Tin Ridges and Grease Marks on Hot-dipped Tinplates. S. Tanaka. (*Tetsu to Hagane*, 1955, **41**, Sept., 919–920). [In Japanese.]—K. B. J.

Hot Dip Aluminium Coating of Steel Wire. M. Tagaya and S. Isa. (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1957, **7**, Mar., 133–140). Fluxes of NH_4Cl or of $ZnCl_2$ with or without other halide additions were examined and the thickness of the Al and Al-Fe layers, their effects on mechanical and corrosion properties in comparison with galvanized wire, and the dissolving time of the coating in solutions over the whole pH range were determined.

Cladding on Carbon Steel Opens New Fields to Titanium. R. C. Bertossa. (*Iron Age*, 1957, **180**, Oct. 31, 59–62). The results of successful experiments at Stanford Research Research Institute to produce Ti-clad carbon steel are described. The price of this material opens new possibilities for employing the protective properties of Ti. The metals are brazed together under inert gas, or, preferably, vacuum conditions. Fine silver and other brazing alloys have been used; small amounts of lithium in the alloy have been found beneficial. The ductility and bond strength of the material is illustrated.—D. L. C. F.

Coating Technique Gets a Boost. (*Chem. Eng. News*, 1957, **35**, Dec. 2, 48). An electrophoretic process for bright Mo deposition is described. The coating is sintered after deposition.

Vacuum Deposition Avoids Embrittlement. V. Dress. (*Iron Age*, 1957, **180**, Dec. 19, 142–145). Cadmium covered parts are made preferably by vacuum deposition for aircraft purposes as electrodeposition often leads to H_2 embrittlement.

Spray Metallization in the Struggle against Corrosion. M. Cauchetier. (*Corros. et Anticorros.*, 1957, **5**, May, 156–159). A review of the spraying of Zn, Al, Pb, Cu, Ni, Sn and stainless steel with a few notes on uses.

Compressed Air and Its Application in Metal Finishing. J. Robertson. (*Electropl. Met. Fin.*, 1958, **11**, Jan., 3–8, 14). Paint and metal spraying processes, chemical bronzing and silvering and salt spray testing, vitreous enamel, flock, polishing sprays and blast cleaning are briefly noted, with notes on pumps and ancillary apparatus and on hazards.

Protective Coatings for Water Distribution Systems. R. F. McCauley. (*J. Am. Water Works Assoc.*, 1957, **49**, Oct., 1303–1309). A laboratory apparatus was developed to test calcium carbonate coatings in a system free from other metals, apart from the Pt electrode and the iron.

Ceramic Coatings Raise Heat Resistance of Super-Alloys. P. A. Huppert. (*Iron Age*, 1957, **180**, Nov. 14, 157–159). Ceramic coatings for use up to 2,500°F. are considered Recently-developed materials make it possible to improve high temperature properties of the super-alloys with better brittleness, elasticity and strength values than in older ceramic coatings. Boron nitride is a basic constituent in many coatings and a table of its properties is given. Details of lithium compounds used as fluxes are given; important salts are the fluoride, chromate, borosilicate, and silicate.—

Here Are Advantages of Conversion Coatings. (*Prec. Met. Mold.*, 1957, **15**, Dec., 54–55, 57). A diagrammatic account of corrosion processes and the formation and operation of phosphate coatings, with notes on chromates.

The Selection and Use of Phosphate Coatings as Pre-Treatments for Organic Finishes. R. F. Drysdale. (*Electropl. Met. Fin.*, 1958, **11**, Jan., 9–14; A review of present-day methods with an account of the coatings produced, composition, structure, thickness, porosity, residues, and resistance to deformation. The ideal coating is described and choice of process discussed.

The Hinac Process: A Substitute for Tinplate. (*Products Fin.*, 1957, **22**, Nov., 76, 78–79). A chemical chrome-coating process is mentioned and exposure tests are shown.

Measurement of Internal Stresses in Electro-Deposited Metals. F. Munoz del Corral and L. A. Rubio Felipe. (*Inst. Hierro Acero*, 1957, **10**, July-Sept., 355–363). [In Spanish]. The apparatus used to measure the internal stress is described and is based upon the formation of a bi-metallic strip between the base metal and the electrodeposit. The radius of curvature of the strip, when freed, is related to the internal stress in the electrodeposit. Experiments show that the values obtained are of the right order of magnitude and reproducible. Results are reported for copper, nickel, and chromium deposits.—P. S.

Performance and Analysis of Chrome Plating Baths. S. Vučkovic. (*Zaštita Mat.*, 1955, **3**, Jan., 5–12). Analysis of main constituents and of impurities is described.

Nickel Plating Is Stress Free. (*Steel*, 1957, **141**, Sept., 30, 78). A nickel plating process is described by which components for afterburners, ramjet and rocket engines are salvaged by making up to their correct size. The method gives stress free, ductile coatings of controlled hardness; stress corrosion is eliminated. The plating bath contains nickel sulphamate.—D. L. C. F.

Electrolytic Production of Four-Component Nickel – Iron – Molybdenum – Manganese and Nickel–Iron–Molybdenum–Copper Alloys. T. F. Frantsevich-Zabludovskaya and K. B. Kladnitskaya. (*Zhur. Prikl. Khim.*, 1957, **30**, (3), 400–406). [In Russian]. An experimental investigation of the electrolytic production of four-component alloys and of some properties of such alloys is described. The method was shown to be applicable to Ni–Fe–Mo–(Mn or Cu). Mn content in the alloy tended to vary because this element exists in the electrolyte in different valency states. With the copper alloy, constancy of composition with respect to all components was obtained, this being checked on a larger laboratory scale. This alloy was shown by X-ray study to be a single-phase solid solution; the Mn alloy was found to consist of an unidentified second phase.—S. K.

Electrolytic Deposition of a Tin–Nickel Alloy from a Chloride–Fluoride Solution. K. M. Tyutina and N. T. Kudryavtsev. (*Doklady A.N.*, 1957, **115**, (3), 580–582). The study of polarization curves of deposition of Sn and Ni from their alloys at different composition of electrolytes suggest the most favourable bath compositions, composition of alloy, temperature, current density, and other factors.—S. I. T.

Finishing Pointers: Diffused Nickel–Cadmium Deposits. H. J. West. (*Met. Fin.*, 1957, **55**, Oct., 74). The process and uses of Ni followed by Cd plating are briefly stated, testing is also included.

Electroplating from the Pyrophosphate Bath. I. Electrodeposition of Single Metals. T. L. Rama Char. (*Electroplating*, 1957, **10**, Nov., 347–349). Studies on the plating of Sn, Cu, Ni, Pb, and Zn are briefly described and optimum conditions given. Preliminary work suggests that Fe and Co could also be plated from pyrophosphate. (29 references). **2. Electrodeposition of Alloys.** (Dec., 391–392, 408). Plating of Sn–Cu, Zn–Cu, Sn–Ni, Sn–Zn, Sn–Pb, and Ni–Cu is outlined.

Galvanising of Cast Iron. J. Rouff. (*Fond. Belge*, 1957, **10**, Oct., 258). Difficulties encountered in galvanizing cast iron are pointed out. Co-operation between manufacturers of castings and galvanizers has been facilitated by specifying chemical composition, microstructure, and surface finish as follows: Total C, 3·00–3·20%, Si 2·50–2·70%, Mn 0·45–0·55%, S 0·08–0·18%, P 0·90–1·20%. Structure: pearlitic, fine regular graphite. Surface finish: no surface defects or siliceous inclusions.—R. P.

Galvanizing: New Ways for an Old Process. A. T. Baldwin and W. H. McMullen. (*Iron Age*, 1957, **180**, Sept. 19, 150–153). Modern practice in the galvanizing industry is described. Fields in which automation or mechanization have developed are noted.—D. L. C. F.

Largest Continuous Strip Galvanizing Line at Inland Steel Co. Plant. (*Ind. Heat.*, 1957, **24**, Sept., 1730–1734, 1736, 1738). A brief account with illustrations and diagrams.

Electrolytic Zinc-Plating of Steel Wires. E. Pyles Lozano and G. M. Gozzo. (*Bol. Assoc. Brasil Met.*, 1957, **13**, Apr., 165–170). [In Portuguese]. The first continuous process installed at Mineração Geral do Brasil Ltda. is described, and although it worked well it had two drawbacks—the use of cyanides in the copper bath and build up of zinc on the roller contacts. These were changed in the second 10-strand line and the first was modified and made a 20-strand line, both consisting of unreeling, electropolish and wash, zinc bath, drying and reeling sequences. Speeds of 19 m per min for 14 gauge and 9·5 m per min for 8 gauge are used.—P. S.

The State of the Steel Surface and Its Relation to the Quality of Tinning and Galvanizing. J. Teindl. (*Sborník Vědeckých Prací Vysoké*

Školy Báňské v Ostravě, 1956, **2**, (5), 41–55). [In Czech]. The effects of steel surface quality on the properties of the protective layer are discussed in detail; the technological processes in the production of steel sheet which affect its surface structure and composition are also considered.—P. F.

Zinc Coating by Diffusion, or Sherardising. (*Tecn. Indust.*, 1957, **36**, June, 659–662). [In Spanish]. The technique of sherardizing is described, and its advantages and field of application are indicated.—P. S.

Concerning the 'Tearing' of Hot-dip Galvanized Coating. H. Bablik, F. Götzl, and E. Nell. (*Metall*, 1957, **11**, Aug., 649–651). The authors treat of the phenomenon of 'spotty' coatings, where the dull 'spots' consist exclusively of the Fe–Zn alloy. An analysis of normal and abnormal coating growth suggests that in the dull localities the reaction between Fe and Zn proceeds at an abnormally high rate and that continuation of the reaction after removal from the bath is responsible for the absence of a pure Zn layer, but the cause of this behaviour is still obscure. The simplest remedy is to employ a bath with 0·06% Al to suppress alloy formation.—J. G. W.

The Application of Precoated Steel Sheets in Industry. F. H. Smith. (*Sheet Met. Ind.*, 1957, **34**, Dec., 915–923). Costs of finishing sheet steel objects and savings by coating of the original sheets are indicated. Advantages of electrozinc coated sheets are mentioned and illustrations of typical uses are shown.

Post-war Development of the Tinplate Industry in Western Europe. I. Western Germany. W. E. Hoare and B. Keysselitz. (*Sheet Met. Ind.*, 1957, **34**, Oct., 761–768). Production and existing electrolytic and hot-dip plants are reviewed.

Presidential Address. [Past, Present and Future of the Steel and Tinplate Industries]. R. Walker. (*Swansea Met. Soc. Adv. Copies*, [1957], pp. 34). A brief review of the development of wrought iron and steel processes and of local tinplate works (with a list of these operating in 1894) and notes on control, enamelling, refractories, and other topics.

Tin Mill Products. (*A.I.S.I. Steel Prod. Man.*, 1957, Oct., pp. 34). A revision of the July 1954 issue, covering manufacture, blackplate, tinplate, terneplate and hollow-ware enamelling stock, blued plate.

The Kinetics of the "Protecta-Tin" Process. O. Jagrovic, B. Miličevic, and S. Jankovic. (*Zaštita Mat.*, 1954, **2**, July, 175–178). A chromate–phosphate passivating process is described.

Filling Bodywork Seams: Perdeck Solder Paints for Tinning Steel Panels. (*Auto. Eng.*, 1957, **47**, Sept., 352–353).

Hot-Dipped Aluminium Coatings. H. L. Kee. (*Prod. Eng.*, 1957, **28**, Oct. 28, 57–59). Steel coating is briefly described and applications and fabrication properties are indicated with a guide to uses.

Recent Developments in Copper Plating. D. E. Weimer. (*Bull. Inst. Met. Finish.*, 1957, **7**, Autumn, 13–24). Decorative use is described and the development of pyrophosphate and other baths noted. Use under Ni is considered.

Relationship Between Hydrogen Solubility and Reboiling Tendency in Enamelling Steels. R. M. Hudson, J. K. Magor and G. L. Stragand. (*J. Am. Ceram. Soc.*, 1958, **41**, Jan., 23–27). Specimens were charged with H_2 at 38° C and this was then determined by warm extraction at 160° C under Hg. Those rated as heavy reboilers occluded considerably less H_2 than those rated as trace or light reboilers.

Coefficients of Expansion in the Practice of Enamelling. J. M. Winkel. (*Inst. Vit. Enamel. Bull.*, 1958, **8**, Mar., 64–67).

De-Enamelling and Re-Enamelling of Sheet Steel. B. B. Kent. (*Inst. Vit. Enamel. Bull.*, 1958, **8**, Mar., 49–54). Caustic de-enamelling tanks are described and their operation discussed; pickling and re-enamelling practice is then outlined.

A Review of Airless and Electrostatic Spray Painting. A. A. B. Harvey. (*Electropl. Met. Fin.*, 1958, **11**, Feb., 47–49). An extract from a forthcoming book.

Painting Hot-Dip Galvanized Steel. J. F. H. van Eijnsbergen. (*Ind. Fin.*, 1958, **10**, Mar., 34–36). Work of the Dutch Galvanizing Institute is summarized.

A Rational Approach to the Surface Treatment of Sheet Iron and Steel Articles. B. van der Bruggen. (*Met. Fin. J.*, 1958, **4**, Feb., 53–60; *Industrie-Lackin-Betrieb*, 1957, **25**, Oct., 278–284). Effects of surface structure, pretreatments, and structure modifications are briefly considered and the methods of painting and finishing, mainly on continuous lines, are discussed and illustrated.

The Use of Mixtures of Zinc Oxide and Zinc Potassium Chromate in Wash Primers. H. F. Clay and V. Watson. (*Electrop. Met. Fin.*, 1958, **11**, Mar., 89–90). ZnO-$(Zn,K)CrO_4$ can be used in synthetic resin vehicles for service in fresh or salt water.

POWDER METALLURGY

The Manufacture and Properties of Metal Powders Produced by the Gaseous Reduction of Aqueous Solutions. J. P. Warner and Sherritt Gordon Mines Ltd. (*Powder Metallurgy Joint Group, I.S.I. and Inst. Met.*, 1957, preprint, pp. 13). Ni, Co and Cu are mainly considered though Fe is mentioned.

Atomisation of Metal and Alloy Powders. J. F. Watkinson. (*Powder Metallurgy Joint Group, I.S.I. and Inst. Met.*, 1957, preprint pp. 7). Stainless steel powder is produced by atomization of liquid metal by high-pressure water jets with, where necessary, a protective atmosphere. Properties of pre-alloyed powders are given. Vacuum melting is advantageous.

Electrolytic Production of Straight and Alloyed Metal Powders. I. Ljungberg. (*J.I.S.I.*, 1958, August, 303–306). [This issue].

Electrolytic Production of Straight and Alloyed Metal Powders. I. Ljungberg. (*Powder Metallurgy Joint Group, I.S.I. and Inst. Met.*, 1957, preprint pp. 7). **Iron Powder.** Production by electrolysis from aqueous solutions and from fused salts is reviewed. **Ferro-Alloys.** Fe-Ni, Fe-Mn, Fe-Mo and Fe-Cr powder preparation by the above methods is outlined.

Experimental Direct Observation of Sintering by Means of High Temperature Metallography. E. B. Simonsen. (*Tidsskr. Kjemi, Bergv. Met.*, 1958, **18**, (1), 9–13). Experimental observation of surface changes during the sintering of compressed copper powder in a vacuum was carried out by the author with a reflecting microscope. The apparatus, the copper used and the experimental method are followed by a description of the course of the experiment and an examination of results.

Effect of Grain Size on the Kinetics of Shrinkage of Sinters of Carbonyl Iron in the α-Phase. G. Cizeron. (*Compt. Rend.*, 1957, **245**, Dec. 4, 2051–2054). Great dependence upon temperature at the initial and later stages of agglomeration was observed.

Powder Metallurgy in Railway Engineering. (*Rail. Gaz.*, 1958, **108**, Apr. 4, 390–392). A general account of the materials used, compacting process, sintering, and uses.

Developments in the Practice of Compacting and Sintering. (*I.S.I. and Inst. Met.*, 1958, March., pp. 63). **Compacting of Powders Using Moulds Made from Reversible Gels.** T. W. Penrice (1–6). **The Continuous Production of Strip by the Direct Rolling Process.** D. K. Worn. (7–13). **The Consolidation of Metal Powders by Hot Working Within Sheaths.** J. Williams. (14–23). Upsetting, forging, extrusion, rolling, swaging and hot pressing are outlined and the choice of sheath material is discussed. Applications are considered. **Developments in Vacuum Sintering Furnaces.** M. Donovan. (24–32). A review of equipment, heating systems and insulation. **Conditions for Effective Vacuum Sintering and Their Realisation in Practice.** O. Winkler. (33–40). Gas adsorption and desorption, sources of gaseous material and practical factors are discussed. **The Pressureless Sintering of Loose Beryllium Powder.** T. R. Barrett, G. C. Ellis and R. A. Knight. (41–49). **Zone Sintering.** J. Antill and M. Gardner. (50–63). Work on Th, V and a refractory material is described.

FERRITES, CERMETS AND CARBIDES

On the Formation and Constitution of Calcium Ferrite. I. Kushima and T. Amanuma. (*Mem. Fac. Eng. Kyoto Univ.*, 1957, **19**, Apr., 178–190).

On the Formation and Constitution of Nickel Ferrite. I. Kushima, T. Amanuma and K. Tanaka. (*Mem. Fac. Eng. Kyoto Univ.*, 1957, **19**, Apr., 191–206).

PROPERTIES AND TESTS

Production Technology of Surface Smoothness Comparators (1–9 classes). A. Sadowski. (*Prace Inst. Mech.*, 1957, **6**, (19), 3–12). [In Polish]. The author discusses the purpose and range of use of smoothness comparators. He describes research on the selection of suitable materials for surface smoothness comparators and discusses their machining technology.

On the Relation between Mechanical Properties and Heat-Treatment of Structural Steel Tubes. K. Kawano. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 983–986). Correlations are obtained between various mechanical properties and amounts of constituents, and the calculated ideal critical diameter.—K. E. J.

Metal Selector. (*Steel*, 1957, **141**, Oct. 28, 169–178). Composition, forms, properties and applications of a large variety of metals are listed. Tables include ferrous castings, alloy steels, H-steels and stainless steels.—D. L. G. F.

Quality Control of High Temperature Alloys. G. T. Harris. (*Met. Prog.*, 1957, **71**, Jan., 90–94). The author describes the progress made in an investigation into the variation and scatter in properties of high-temperature alloys, arising primarily from a consideration of the materials available to withstand typical gas turbine blade operating conditions at temperatures of the order of 1700–1800°F. The use of vacuum melting as a possible method of reducing the variation in properties is considered.—G. F.

The Associated Flow Rule of Plasticity. D. R. Bland. (*J. Mech. Phys. Solids*, 1957, **6**, (1), 71–78). Work hardening and the linearity hypothesis of D. C. Drucker are equivalent to the hypotheses of the existence of the plastic potential and its identity with the yield function. It is suggested that these are alternative statements of a new physical law. The flow rule at singular points on a yield surface is found by considering the actual yield surface as the limit of a sequence of regular surfaces. This has different consequences for work-hardening and non-hardening materials.

Deformation Studies in Metal Working Processes. H. P. Tardif. (*Steel Proc.*, 1957, **43**, Nov., 626–632). The various methods for tracing metallic flow in deformation processes are reviewed, mostly with reference to non-ferrous metals. Plasticene and X-ray methods are also considered.

Study in the Hot-workability of Steels. III. Hot-working Properties of Austenitic Stainless Steels. (*Tetsu to Hagane*, 1955, **41**, Sept., 1069–1071). [In Japanese.]—K. E. J.

Observation of Dislocation Sites in Iron. F. W. C. Boswell. (*Met. Prog.*, 1957, **72**, Dec., 92–93). The author briefly describes a technique for investigating etch pits on iron, and discusses the conditions under which they are formed. He shows that they occur at the points of emergence of individual edge dislocations.—G. F.

Experimental Research on the Order–Disorder Transformation of Iron-Cobalt Alloys. T. Yokoyama. (*Bull. Faculty Eng. Yokohama Nat. Univ.*, 1954, **3**, 1–13). Alloys were prepared from analysed materials in a Tammann furnace in H_2. Hardness, thermo-electric force, density and resistance were measured and transition points are discussed in terms of order–disorder phenomena.

Vacancies and Other Point Defects in Metals and Alloys. (*Symposium, Metal Physics Committee Institute of Metals*, 1957, Dec., *at Harwell, Advance Copies*, pp. 198). **Point Defects and the Mechanical Properties of Metals and Alloys at Low Temperatures.** A. H. Cottrell. (1–39). A review with 148

references. Radiation hardening of iron and its removal by annealing are included. **Effect of Lattice Defects on Some Physical Properties of Metals.** T. Broom and R. K. Ham. (41–78). 141 references. Mainly concerns Cu and Ni with notes on other non-ferrous metals. **Point Defects and Diffusion in Metals and Alloys.** W. M. Lomer. (79–98). A review of present ideas. (54 references). **Point Defects and Mechanical Properties of Ionic Crystals.** P. L. Pratt. (99–130). **Point Defects Near the Surface of a Metal.** E. C. Williams and P. C. S. Hayfield. (131–157). **Point Defects and the Mechanical Properties of Metals and Alloys at High Temperatures.** D. McLean. (159–198). Creep is interpreted, and data for pure metals, including pure α-iron and for solid solutions such as austenite, and the development of creep-resisting alloys are reviewed. (109 references.)

Properties of Materials at High Rates of Strain. K. N. Leibovic. (*Metallurgia*, 1957, **56**, Nov., 239–241). The properties of engineering materials under the high rates of strain encountered in arduous conditions of service are currently of great interest. As examples, the author discusses the propagation of stress waves, elastic and plastic strains, and the effect of high strain rate on yield and fracture.—G. F.

Rate of Strain Nomograph. W. H. Mather. (*Met. Prog.*, 1957, **72**, Sept., 96, 98-B). This nomograph is designed to give a close approximation to strain rate in mechanical testing. An example of its use is given.—G. F.

The Automatic Recording of Strains Measured with the Maihak Extensometer. C. Rohsbach. (*V.D.I.Z.*, 1956, **98**, Sept. 11, 1541–1548; Eng. Dig., 1957, **18**, Jan., 6–9). A vibrating-wire extensometer, its theory and its uses, are described, with circuits for visual use and for recording.

Effect of Metallurgical Variables on Transition Behaviour in Charpy Slow-Bend and Impact Tests. C. E. Hartbower. (*Welding J.*, 1957, **36**, Sept., 401s—409s). Comparisons between transition behaviour in slow-bend and impact revealed a complex interplay of velocity effect, and quench and strain aging. The effects of C and Mn on impact transition behaviour were found to be consistent with published data—U. E.

[Design of a Torsion Testing Machine for High Temperatures.] K. Kugai. (*Tetsu to Hagane*, 1955, **41**, Sept., 1056–1058). [In Japanese.] Data are given for the relationship of shearing stress to number of revolutions at 400°, 500°, 800° and 1300°C, and for the max. mean shearing stress and number of twists to failure of a specified test-piece for temperatures between 400° and 1400°C. Examples of experimental results from the instrument are given.—K. E. J.

Fatigue Crack Propagation in Torsion. J. A. H. Hult. (*J. Mech. Phys. Solids*, 1957, **6**, (1), 47–52). Stress and strain redistribution in front of a growing crack in a twisted bar is derived assuming ideal plasticity. This is used in connexion with a simple fracture criterion to determine the initial rate of growth of a fatigue crack.

Watch Out for Compression Loads. L. A. Yerkovich. (*Prod. Eng.*, 1957, **28**, Dec. 9, 72–75). Metals are not as strong in compression as in tension, the effects of cold work, temperature effects and creep are sometimes overlooked. These are here outlined as well as the contrast of sheet with bar properties, and the testing of compression strength is also described. A stainless steel is shown as well as Al and Co alloys.

Relation of Charpy Impact Properties to Microstructure of Three Ship Steels. W. S. Owen, D. H. Whitmore, M. Cohen and B. L. Averbach. (*Welding J.*, 1957, **36**, Nov., 503s–511s). The micrographs of three types of ship steel are compared. It is found that cooling rate, and probably variation in composition, can produce effects which influence the transition temperature but which cannot be measured by optical microscopy.

The Effect of Impact Loading on the Static Yield Strength of a Medium-Carbon Steel. J. D. Campbell and C. J. Maiden. (*J. Mech. Phys. Solids*, 1957, **6**, (1), 53–62). Annealed medium-carbon steel was subjected to rapidly-applied compressive loads for times of $\sim 10^{-4}$ sec. of a magnitude two to three times the static upper yield stress and permanent deformation varied from 1·2% down to very low values. Static yield stress is much reduced and is related to number of dislocations freed from their carbon atmospheres during impact. It is greatest after impact producing 1% permanent strain. Tests at −84°C. show that the effect depends upon the permanent strain and not directly upon stress or duration of load.

Effect of Specimen Geometry on Charpy Low-Blow Transition Temperature. G. M. Orner and C. E. Hartbower. (*Weld. J.*, 1957, **36**, Dec., 521s–527s). Within limits of specimen size and notch type, the temperature is independent of specimen geometry. A variation of the test is described which permits separation of the crack initiation and propagation stages. Further developments are being studied.

Mechanical Properties of Metals. (*Mech. World*, 1957, **137**, Dec., 549–550). A review is presented of recent work on dynamic loading, stress rupture testing, brittle fracture, transverse strength, creep, and the notch and torsion tests.

The Effect of Impact on Beams and Welded Structural Connections. P. J. Brennan and H. A. B. Wiseman. (*Welding J.*, 1957, **36**, Oct., 465s–472s). It is shown that for the theory used the computed work at failure under impact exceeded the work at failure under static loading for similar beams and welded connections. The ratio being 1·2/7·6. A linear relationship exists between work required for failure in the weld and the area of the failure plane of the weld.—U. E.

An Evaluation of the X-Ray Diffraction Method of Stress Measurement with a Comparison to Dissection Methods of Residual Stress Measurement in Hardened Steel. M. Miller, E. Mantel, and W. Coleman. (*Proc. Soc. Exper. Stress Anal.*, 1954, **15**, (1), 101–112). A simple fixture for applying a mechanical strain was used and comparison made by X-ray and strain gauge techniques. The mean deviation was ± 5000 psi. Effects of geometrical factors are also considered. Direct measurements were made by dissection on carburized blocks including work on gear and bar specimens. X-Rays have an advantage for surface measurements and are comparable with mechanical methods in general precision.

Analysis of Residual Stress in Ground Surfaces of High-Temperature Alloys. R. L. Halverstadt. (*Trans. ASME*, 1957, preprint 57-SA-62, pp. 12). The effects of grinding wheel speed and hardness, grinding fluid, down feed and work speed on stress level on gas-turbine alloys are examined. Stresses can be reduced by using lower speeds and feeds, increasing work speed and by the use of sulphurized oil.

A Contribution to the Strain-Ageing of Unalloyed Constructional Steels. F. Erdmann-Jesnitzer and G. Haussler. (*Neue Hütte*, 1957, **2**, July, 409–417). A description is given of the process of strain ageing in two soft unalloyed steels after cold-working by straining and torsion, with reference to Brinell hardness, the micro-hardness of the α-iron mixed crystal, and notched bar temperatures as a function of total reduction, duration of ageing, storing temperature, and steel quality. The recrystallization of strain-aged samples was studied by determination of Brinell and microhardness and of grain size, and by X-ray reflection diagrams.—L. J. L.

A Discussion on Work-Hardening and Fatigue in Metals. (*Proc. Roy. Soc.*, 1957, **242A**, Oct. 29). **Work-Hardening and the Initiation and Spread of Fatigue Cracks.** N. F. Mott. (145–147). **The Mechanism of Work-Hardening and Slip-Band Formation.** J. Friedel. (147–159). **The Energy Stored in Fatigued Metals.** L. M. Clarebrough, M. E. Hargreaves, G. W. West, and A. K. Head. (160–166). **The Hardening and Softening of Metals by Cyclic Stressing.** T. Broom and R. K. Ham. (166–179). **Annealed Metals Under Alternating Plastic Strain.** W. A. Wood and R. L. Segall. (180–188). **The Initial Fatigue Crack.** G. C. Smith. (189–197). **Slip-Band Damage and Extrusion.** P. J. E. Forsyth. (198–202). **The Fatigue and Ultimate Tensile Strength of Metals between 4·2 and 293° K.** R. D. McCammon and H. M. Rosenberg. (203–211). **Some Observations on the Spread of Fatigue Cracks.** N. E. Frost and C. E. Phillips. (216–222). Observations on mild steel are reported. **Speed Effect in Fatigue.** P. G. Forrest. (223–227).

On the Methodical Investigation of the Deformation of Metals at High Temperatures. E. I. Bol'skii and R. I. Tomilin. (*Zavod. Lab.*, 1957, **23**, (8), 957–958). The method described in this article has made possible the investigation of a series of problems connected with the behaviour of metals during deformation not only at ordinary temperatures but also at higher temperatures right up to the melting point.—L. H.

Analysis of Second-Type Strains of the α-Phase of Hardened and Tempered Steel. L. I. Lysak. (*Izvest. Akad. Nauk SSSR, Seriya Fiz.*, 1956, **20**, (6), 624–630). [In Russian]. The author proposes that experimentally determined second-type distortions of the martensite crystal lattice in steel should be considered as the overall effect of the following factors: (*a*) hardening distortions produced by phase change; (*b*) coherent distortion produced inside the martensite crystals during the initial stage of the decomposition of the supersaturated α-solid solution; (*c*) dispersion distortions also produced inside martensite crystals by the separation of carbide-phase crystals from the solid solution. On the basis of results of previous investigations he advances probable rules for the change of each of the above types of lattice distortion during the tempering of steel.—S. K.

Influence of Texture on the Intensity of Interference Lines in the Investigation of Massive Deformed Specimens. M. Ya. Fuks and G. V. Dobrovol'skaya. (*Izvest. Akad. Nauk, Seriya Fiz.*, 1956, **20**, (6), 679–683). [In Russian]. An account is given of experiments in which specimens of Cr–Ni–Mo steel were plastically deformed by linear extension at room and elevated temperatures with both brief and prolonged application of the load. Portions with various degrees of residual deformation, up to 150%, were examined with a Pines-system sharp-focus X-ray tube. A specimen deformed at 500° C with loading for 96 h was used as the standard for comparing results. The significance of the results obtained for the interpretation of X-ray investigations of deformed states is discussed.

Deformations, Fractures and Dislocations in Crystalline Metal Structures. A. Roos. (*Genie Civil*, 1957, **134**, May 1, 198–205). A review of the theory of dislocations and their effects on mechanical properties and corrosion.

An Attempt to Determine the True Value of Yield Stress during Triaxial Plastic Deformation. Z. Wusatowski. (*Arch. Hutn.*, 1956, **1**, (4), 283–317). An improvement of the formula resulting from Huber's theory of max. shear strain energy by measuring real deformations instead of stresses. Formulæ covering different ranges of values of the coefficients are obtained. (50 references).

Limited Life Design: A Survey of the Problem. J. A. Pope, B. K. Foster, and N. T. Bloomer. (*Engineering*, 1957, **184**, Aug. 23, 236–241; Aug. 30, 275–278). Design of structures where fatigue is the limiting factor is discussed. Fatigue tests results and the use of values obtained from them are described. The change from static design for infinite life to "fail safe" concepts is explained. (17 references).

On the Laboratory Estimation of the Susceptibility of Steels to Delayed Failure. S. S. Shurakov. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 707–711). [In Russian]. During the study of hardened steels, it was found necessary strictly to regulate the time from the very start of the hardening process to the time of test of the specimen. Also it was found necessary to use notched specimens for ductile steels and smooth specimens for brittle steels.

Probabilities in Fatigue Testing. F. E. Richart. (*Metal Prog.*, 1957, **72**, Aug., 111–112). A brief review of the scatter obtained in

fatigue testing and the advantage of calculating curves representing the % probability of failure is given.—B. G. B.

The Effect of Understressing on the Fatigue Properties of Coarse Flake Graphite Cast Irons. K. B. Palmer. (*Brit. C.I. Res. Assoc. J. Res. Dev.*, 1957, **6**, June, 660–665). Previous workers have reported an increase in fatigue limit due to understressing but tests carried out by the B.C.I.R.A. did not show any increase. A further series of tests, carried out on lower strength cast irons typical of those used by other workers is reported, and again no increase in fatigue limit was found.—B. G. B.

Delayed-Yield Time Effects in Mild Steel Under Oscillatory Axial Loads. R. O. Belsheim. (*Trans. ASME*, 1957, **79**, Oct., 1619–1626). Apparatus is developed for superposition of oscillatory and static loads on tensile specimens. Dynamic yield-points were observed 5–50% above static yield-point and delayed-yield times of 1000–10 millisec. Any surface flaw or scratch prevented any appreciable increase of yield-point.

Influence of the Fineness of Division of Graphite Grains and Their Structure on the Endurance of Cast Iron to Alternating Stresses. J. Pomey, L. Abel, R. Lafont, P. Mathon, and A. Royer. (*Compt. Rend.*, 1957, **245**, Oct. 14, 1311–1314). Shape is of little importance but the effect of graphite decreases with particle size until it reaches a uniform value. The effect of stress gradient is shown by means of perforated specimens.

Some Important Problems in the Study of Fatigue Testing. New Results on Actual Deflection Phenomena in a Rotating Beam Test Piece in Fatigue Testing by a New Method. Y. Asakawa. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 140–143). [In Japanese]. Deflection of a rotary bending test-piece was determined by the air-condenser method, and was found not to be constant under constant loading but to vary cyclically in accordance with the cycle of the rotary piece. These results suggested a stroboscopic method, which has been used to determine the deflection of the specimen at various phases of rotation.

Fatigue Symposium. G. M. Canta. (*Metaalinstituut Publ. T.N.O. No.* 45, *Oct.*, 1956). [In Dutch]. The author describes briefly the main features of three types of fatigue testing machines, namely the Wohler, Losenhauser, and Schenck, to illustrate such machines generally and then goes on to discuss the results of some calibration tests in conjunction with indications on the trend in developments.

Fatigue Machine Tests Designs and Materials. (*Iron Age*, 1957, **180**, Sept. 12, 134–135). A type of machine developed in Germany by Losenhausen for fatigue testing full-size structures, is described. A series of loading cylinders are governed by a control console, a pulsator and a programmer. Fluctuating or alternating loads can be applied.—D. L. G. P.

Fatigue Testing of Sheet Metal: A Description of the "Vibrophore" Machine and Its Applications. G. Földes. (*Sheet Met. Ind.*, 1957, **34**, Oct., 749–751). An account of the Swiss-made apparatus with a testing frequency of 50–200 cycles/sec and a maximum bending moment in one direction of 420 ft lb or ± 210 ft lb in alternate stress tests is given.

Fatigue Under Resonant Vibrations Considering Both Material and Slip Damping. B. J. Lazan. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (1), 1–20). A lecture. Data are presented showing the significance of both material and slip damping and the important parameters for the calculation of both. It is shown that the two are not directly comparable and parts of joints can easily be conceived in which one or the other will predominate. At high stress, material damping is usually the more important.

Fatigue Testing of Turbine Buckets. A. Herzog. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (1), 21–34). A testing method substituting axial load for centrifugal stress is described, stress diagrams are given and fatigue strengths of Stellite 21 and S–816 buckets are shown. Service and test failures are illustrated.

Time Saving in Statistical Fatigue Experiments. N. T. Bloomer. (*Engineering*, 1957, **184**, Nov. 8, 603). Statistical methods for reducing the number of observations and the numbers run to destruction are explained.

On Shot for Peening. IV. The Relation between Residual Stress and Fatigue Strength. M. Uchiyama and K. Kamishohara. (*Tetsu to Hagane*, 1957, **43**, May, 533–537). [In Japanese]. Results from polished Si–Mn steel specimens show that the residual compressive stress caused by peening improves the fatigue resistance of the specimen. The hardness of the shot is only significant insofar as it produces residual stress. As-cut wire shot has a deleterious effect on fatigue strength. (16 references).—K. E. J.

State of Knowledge Concerning the Effect of Specimen Size on Fatigue Limit. M. Hempel. (*Draht*, 1957, **8**, Sept., 385–394). This survey, containing 72 references, deals with the size effect in fatigue. The author concludes from available data many of which are quoted *in extenso*, that the fatigue limit is influenced by factors other than the stress gradient and that allowance must be made for possible plastic deformation. He recommends further work on very small and very large specimens with sharp notches and considers statistical evaluation indispensable.—J. G. W.

An Investigation into Residual Stresses and the Fatigue Strength of Steel. C. O'Connor. (*J. Inst. Eng. Australia*, 1957, **29**, Sept., 227–234). Stresses were produced by cold bending structural steel flat specimens and unloading. Holes were drilled in the strained region and the pieces tested in fatigue under axial fluctuating load. It is unlikely that detrimental effects are produced by the amount of strain applied, none was observed.

Fracture of a Steel Tube along a Flange. (*Cien. Tecn. Solda.*, 1957, **7**, Sept.-Oct., pp. 4). [In Spanish]. This article consists of one of the replies, in a standard form, to the Fatigue Testing Committee of the International Institute of Welding; strict anonymity of its origins is preserved. Fracture occurred after 350 h service near the welded flange connecting a 0·10/0·13% carbon steel tube into a compressor circuit and a report of the subsequent examination is provided. The weld was found to be perfectly sound, and the failure is believed to result from insufficiently rigid foundations causing excessive vibrations hence high stresses at the flange. The flange design was also unsatisfactory, one with a thicker, tapered section at the other end of the tube had given no trouble.—P. S.

New Machine for the Study of Static and Fatigue Properties by Triaxial Tensions. G. Welter and A. Choquet. (*Met.-Corrosion-Indust.*, 1957, **32**, July-Aug., 300–312). A description is given of this new machine and of the method of carrying out measurements. Results obtained on a number of materials, including Armco iron, are given and discussed.

Theoretical Investigation of Creep and Crack Density Studies in Stresscoat. P. N. Murthy. (*Proc. Soc. Exper. Stress Anal.*, 1957, **15**, (1), 57–64). Viscoelastic behaviour is investigated and an empirical formula to fit experimental curves is obtained.

A New Approach to the Problem of Creep. J. Glen. (*J.I.S.I.*, 1958, August, 333–343). [This issue].

Creep Characteristics of Type 347 Stainless Steel at 1050 and 1100° F in Tension and Compression. M. J. Manjoine. (*Trans. A.S.M.E.*, 1957, **79**, Nov., 1921–1928). Cold-drawn and stress-relieved tubular specimens flow plastically at these temperatures at stresses below the 10,000-h rupture strength. Precipitation causes an extended period of abnormally high creep resistance, increasing with decreasing stress and longer for compression than for tension. Creep and rupture strengths are lower than for annealed bar stock.

Carbides and the Creep Strength of Chromium–Molybdenum–Vanadium Steels. W. Koch, A. Krisch, and A. Schrader. (**Arch. Eisenhütten.*, 1957, **28**, Aug., 445–459). A report is presented of metallographical and electron microscope experiments to investigate structural changes occurring in the course of initial heat treatment and in creep strength tests for two steels having 0·19% C, 1·3% Cr, 1·05% Mo, and 0·55% V, and 0·17% C, 1·1% Cr, 1·15% Mo, and 0·35% V respectively.

The Creep of Metals. N. P. Allen. (*Tekn. Uke.*, 1957, **104**, Sept. 26, 779–787). [In English]. A review of the mechanism and factors influencing creep and of the development of creep-resistant alloys is given. Steels are included.

Some Results of American Long-Term Creep Tests on Tube Steels, and Their Use in the Determination of Permissible Stresses. F. Eberle. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 702–706). American procedures for determining long-term heat-resistance are fundamentally similar to German methods. Results are reported of tests at 455–980° C for periods up to 40,000 hours on unalloyed steel with 0·22% C, alloyed steel with 0·5% Mo, 2·25% Cr and 1% Mo; 18% Cr and 10% Ni; 18% Cr, 12% Ni and Ti or Nb, with 16% Cr, 13% Ni and 3% Mo, and 25% Cr and 20% at various conditions of heat treatment.—L. J. L.

Results of Long-Term Creep Tests on Ferritic and Austenitic Steels. A. Constant. (**Arch. Eisenhütt.*, 1957, **28**, Nov., 695–702). The results are reported of co-operative French studies on heat-resistant steels. These studies proceed on the assumption that, in order to obtain a firm basis for calculating, it is advisable to investigate a considerable number of melts in tests of about 10,000 hours' duration and to check the figures extrapolated from the results by a few experiments of longer duration.—L. J. L.

Evaluating the Results of Long-term Creep Tests. (**Arch. Eisenhütt.*, 1957, **28**, Nov., 687–694). This is a discussion, by K. Schaar, E. Houdremont, W. Ruttmann, N. P. Allen, G. Krüger, K. Richard, M. Werner, R. Montandon, and F. Eberle of the paper by G. Bandel and H. Gravenhorst in *Ibid.*, 253–258, on creep formulæ, plastic deformation, etc.

Experimental Apparatus and Methods for Long-Term Creep Tests. K. G. Olson. (**Arch. Eisenhütt.*, 1957, **28**, Nov., 679–685). A description is given of apparatus and methods for the determination of creep and fracture development at high temperatures both under constant and fluctuating loads and temperatures. Swedish work is discussed.—L. J. L.

The Belgian Commission for the Testing of the Long-Term Strength of Metals at High Temperatures. O. L. Bihet. (**Arch. Eisenhütt.*, 1957, **28**, Nov., 675–677). The work of the commission is described with particular reference to the method used to determine the long-term heat-resistance of individual steels, which method represents a first attempt to approximate to accurate statistical procedures in this field.—L. J. L.

Changes in the Creep Rate of an Unalloyed Steel During Long-Term Creep Tests. A. Johansson. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 712–713). The creep curve was plotted at 450° C for an unalloyed steel with 0·16% C in the normalized state in tests lasting up to 21000 hours.—L. J. L.

Scatter of the Results of Long-Term Creep Tests. W. Schlütter. (**Arch. Eisenhütt.*, 1957, **28**, Nov., 717–719). Using as examples two tube steels, it is shown that a scatter of ± 20% must be expected in tests by different testing stations of melts of various manufacture but of the same standard steel.—L. J. L.

Long-Term Creep Tests on Small Samples, and Their Evaluation. A. Keller and W. Stauffer. (*Arch. Eisenhütt.*, 1957, **28**, 719–726). Results are reported of tests on unalloyed steels, low-alloy steels with Mo, Cr–Mo, Mo–V, Cr, Mo–W, and V, and in particular on high-alloy steels with 12% Cr, 25% Cr and 20% Ni, 18% Cr and 8% Ni, 18% Cr, 8% Ni and Ti, 18% Cr, 8% Ni and Nb, 16% Cr, 13% Ni and 3% Mo, 16% Cr, 13% Ni, 3% Mo and Nb, steels with more than 7% Co and nickel alloys.—L. J. L.

The Statistical Evaluation of the Results of Long-term Creep Tests as a Basis for the Establishment of Minimum Values. H. Zschokke. (*Arch. Eisenhütt.*, 1957, **28**, Nov., 726–729). The statistical character of creep strength was demonstrated by long-term tests at 550° C under stresses of 30, 22, and 20 Kg/mm² on melts of a cast steel with 3% Cr, 0·6% Mo, 0·3% V and 0·5% W.—L. J. L.

Heat Checking in Die Casting Dies. H. K. Barton. (*Machinery*, 1957, **91**, Oct. 25, 982–

990). Failure by surface cracking is discussed and stages of crack formation and causes are reviewed. Measures for retarding the process are considered.

Shelling of Railway Wheels. B. B. Hundy. (*Rail. Steel Topics*, 1957, **4**, Autumn, 19–35). An investigation of the causes is reported showing stress distributions, effects of wheel diameter and frictional drag, pitting strength and the effects of hardness, thermal effects, service conditions, wear, and microstructures. (24 references).

The Hardness of Metals. M. J. Druyvesteyn and M. A. Meyer. (*Technical and Scientific Journal for the Joint Metal Industry*, 1952, **7**, June 30, 203–206; Translation T.M.S. 328). Methods of measurement are considered and factors changing the hardness are discussed with reference to crystal form.

Brinell Hardness Testing. L. A. Welt. (*Met. Treating*, 1957, **8**, Sept.-Oct., 20, 65). A general review of the method and recent apparatus is given.

Microhardness Testing. T. E. W. Preston. (*Metalw. Prod.*, 1957, **101**, Oct. 11, 1833–1836). A description of the G.K.N. tester, which is a pyramid diamond indentation device making impressions as small as 7 μ in diagonal, and of its uses are given.

The Determination of the Micro-Hardness of Metals in Their Condition of Stress-Deformation. V. D. Lisitsyn. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 711–715). [In Russian]. A special apparatus was constructed based on the instrument P.M.T. 3 which measures the applied force for instantaneous deformation of specimens. The results of many measurements produced interesting statistical data. (In Kg per mm²) Grains of Al, 23, of brass, 70, of ferrite, 98, and of austenite, 162.—L. R.

A New Standard Hardness Testing Machine. R. S. Marriner and F. C. P. Mason. (*Machinery*, 1957, **91**, Nov. 22, 1225–1230). The development of a diamond indenting machine is described.

Use of the End-Quench Test in the Prediction of the Results Obtained in Flame-Hardening of Steel Castings. H. W. Grönegrass. (*Stahl u. Eisen*, 1957, **77**, Oct. 31, 1619–1623). The author studied the relation between the hardness obtained in the end-quench test and in flame-hardening on a variety of steels. He found that there is a definite relation between end-quench test and flame-hardening in unalloyed, manganese- and manganese–silicon-alloyed steels, but that there is no relationship with chromium and molybdenum-alloyed steels. However, heating rotating end-quench test-pieces with the flame gave comparable results.—T. G.

On the Hardness of Martensite and the Relation between Phase Diagram and Hardness. I. On the Hardness of Fe–Ni Alloys due to Heat Treatment. J. Matsuoka. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 181–185). [In Japanese]. The investigations were made to assist the study of the high hardness of martensite in carbon steel. Hardness due to heat treatment was examined by means of the degree of annealing by quenching and the velocity of lattice transformation, and the extent of the annealing effect was determined by the temperature interval after lattice transformation. (15 references).—K. E. J.

The Mechanical Properties of Hard-Drawn Spring Wires. F. Bleilöb and E. Schücker. (*Stahl u. Eisen*, 1957, **77**, Oct. 3, 1362–1368). The authors suggest a revision of DIN specification 2076 for testing U.T.S. of spring wire and a new classification of hardness in relation to wire dia. The relationship between dia., max. shear stress and reduction in area at fracture is a good enough criterion for the properties of spring wire.—T. G.

Metallographic Uses of Hot Hardness. J. Pomey, A. Royer, and J. P. Georges. (*Compt. Rend.*, 1957, **245**, Oct. 21, 1424–1427). A method of measuring hardness at constant temperature and constant load by measurement of flow by penetration as a function of time. A relation to extension under tensile stress is obtained and the method is shown to be rapid and to require very little of the material. Measurements on steels and on Co alloys are shown.

Hardness and Microhardness of Ferritic Casting Iron. K. I. Vashchenko, R. P. Todorov, and P. A. Varenik. (*Lit. Proizv.*, 1956, (10), 19–23). [In Russian]. For the determination of the hardness of cast iron with varying content of Mn and Si and the microhardness of contained ferrite, specimens were cast in moulds and in marl. The experiments are recorded in detail with full statistical data.

The Effect of Ageing of Supercooled Austenite on the Properties of Hardened High-Speed Steel. K. Monma and S. Uemura. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 65–69). [In Japanese]. Supercooled austenite of high-speed steel precipitates carbides before the $\gamma \rightarrow \alpha$ transformation. Experimental work on the influence of such precipitation on the properties of the hardened steel is reported. Samples were austenitized at 1300° C, quenched in a metal bath at 600° C for a time and then oil-quenched; they then contained no residual austenite, and in tempering showed no secondary hardness. The differences between these and normally-quenched specimens were studied metallurgically.—K. E. J.

On Ageing of Malleable Steel and Consequent Changes in its Characteristics in Deformation. Å. Josefson. (*Värm. Bergsmann. Ann.*, 1957, 90–119). Primary effects of ageing and its theoretical course and interpretations of these effects with examples are discussed, together with changes in brittleness of welding steel for construction. (17 references).

Measurements of Internal Friction on Slightly Strained Iron-Carbon Alloys. W. Wepner. (*Acta Met.*, 1957, **5**, Dec., 703–710). [In German]. Time-dependence of precipitation was measured on pure iron with addition of < 0·02% C with or without deformation up to 5% strain. The undeformed specimen followed the general law of precipitation, the strained specimen followed Cottrell's relation for movement of C to dislocations. The precipitation curve showed two stages, at 38° C the order was reversed and at 80° they were separated by a period in which little precipitation took place. Mechanism is suggested.

The Effects of Ageing and Straining on the Internal Friction of Hydrogen Charged 1020 Steel at Low Temperatures. L. C. Weiner and M. Gensamer. (*Acta Met.*, 1957, **5**, Dec., 592–694). A peak appears at 106° K, reaches a maximum and disappears. Another peak at 50° K has also been observed due to stress-induced diffusion of interstitial H_2. A model involving the dragging along of H_2 by oscillating dislocations is advanced.

The Effect of Nickel on Embrittlement in Long-Term Creep Tests of Chromium–Molybdenum and Chromium–Molybdenum–Vanadium Steel Castings. W. Felix. (*Arch. Eisenhüttenwesen*, 1957, **28**, Nov., 710–712). Creep tests have been carried out at 550° C on Cr–Mo steel castings with 0·1% C, 0·5% Cr, 0·8% Mo and 0·1 to 1·5% Ni, and on Cr–Mo–V steel castings with 0·1% C, 0·5% Cr, 0·8% Mo, 0·25% V and 0·1 to 0·6% Ni.—L. J. L.

Position of the Cold-Shortness Threshold in Temper Embrittlement. V. I. Prosvirin and E. I. Kvashnina. (*Metallov. Obra. Met.*, 1955, Mar., 17–20). An etching medium is recommended for metal in the brittle state. It is found that when temper brittleness develops the ductile–brittle transition temperature increases, and it is lowered by increased duration of tempering while grain size increases. In steels not susceptible to temper-brittleness the ductile–brittle transition temperature does not change; it is a reliable criterion of susceptibility.

The Influence of Stress-Relieving on the Initiation of Brittle Fracture In Welded Plate Specimens. R. Kennedy. (*Brit. Weld. J.*, 1957, **4**, Nov., 529–534). The effects of pre- and post-welding stress relief on initiation of brittle fracture from a notch defect in 3 ft butt-welded plate are investigated. With untreated specimens fracture occurred at low applied stresses in the range + 10° to − 25° C but in absence of residual stress fracture did not begin, even as low as − 50° C, until stressed approximately to the yield-point. Treatment for 1 h at 650° was fully effective.

Twinning and Brittle Fracture in Steels. A. Kochendörfer and H. Scholl. (*Arch. Eisenhütten.*, 1957, **28**, Aug., 483–488). The results of studies of notched-bar bend test samples under the optical and electron microscopes are reported. Three types of deformation twinning were found to occur in steels: (1) wide twins having irregular edges and contractions, (2) narrower twins having smooth, parallel edges with indentations, and (3) narrow twins having smooth and parallel edges. It is concluded that there is no causal connection between twinning and brittle fracture.—L. J. L.

Calculation of the Tendency to Brittleness in Steels under Factory Conditions. E. M. Shevandin. (*Zavod. Lab.*, 1957, **23**, (8), 949–953). [In Russian]. As a rule the tendency to brittleness in metals is presented in the form of diagrams constructed from the data obtained from experiments, between co-ordinates of the critical temperature of brittleness and the inverse of the radius from the notch. For different materials, different relations between indices from characteristic diagrams can be used.—L. R.

Susceptibility of Steel to Brittle Fracture. Gočau. (*Centre Doc. Sidér. Circ. Inform. Tech.*, 1957, No. 8, 1675–1688). A review is made of published data in particular that of T. S. Robertson. The results obtained by the methods of Robertson, Van de Veen, Pellini and with the Charpy V-test are compared.

On the So-called 475°-Embrittlement in Fe–Cr–Al Electrical Resistance Wire Alloys. N. Nagai and A. Higuchi. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 77–81). [In Japanese]. A systematic programme of research on four types of Fe–Cr–Al alloy showed that the 475°-embrittlement is caused by the formation of the superlattice Fe_2Cr, one of those in the Fe–Cr system also found with high-chromium ferritic stainless steels. (13 references).—K. E. J.

Brittleness of Steel at High Temperature. E. Yajima and K. Furusawa. (*Nippon Kinzoku*, 1954, **18**, Mar., 153–158). [In Japanese]. Brittleness is deduced from elongation measurements on various carbon steels between 700° and 1050° C. Except for Armco iron, all samples showed two regions of brittleness. One, just above the A_1 point, is attributed to the co-existence of α and γ solid solutions. The other is at a higher temperature, the minimum elongation being at approx. 850° C; it is attributed to the recrystallization of austenite and precipitation of aluminium nitrides. (11 references).—K. E. J.

Analysis of Stresses and Strains Near the End of a Crack Traversing a Plate. G. R. Irwin. (*J. Appl. Mech.*, 1957, **24**, Sept., 361–364). A study of the theory of brittle fracture.

The Brittle Fracture of Metals at Atmospheric and Sub-Zero Temperatures. C. F. Tipper. (*Met. Rev.*, 1957, **2**, (7), 195–261). A review of steel and non-ferrous metals is given. (247 references).

The Effects of Alloying Elements on Temper-Brittleness. I. E. Kontorovich. (*Fiz. Met.*, 1956, **3**, (3), 553–555). Effects of Al, Be, Ti, and Nb are reported. The cause, either precipitate formation or grain size, is discussed and the good effects of Al and Be noted. It seems probable that several factors are concerned. Part of the increased impact resistance may be due to increased boundary layer strength.

The Present Position of Studies on Brittleness in Steel. (*Génie Civil*, 1957, **134**, Dec. 1, 488–494). A review prompted by low-temperature failures of steel constructions on the impact and triaxial resistance of steels of various types over a range of temperature. The effects of heat treatment are extensively discussed and related to composition and microstructure.

Influence of Carbide Forming Elements on the Tempering Brittleness of Steel. V. I. Prosvirin and E. I. Kvashnina. (*Vestnik Mashin.*, 1955, (2), 58–66). [In Russian]. Parallel investigations were conducted by various methods into the kinetics of brittleness during isothermal heating at temperatures most convenient for its development (~ 500°), also into the magnitude of the impact viscosity at lower temperatures. The influence of Mn, W, Ti, and V and also Nb have been studied.

Some Peculiarities in the Development of Heat Brittleness of Austenitic Steel EI 673. V. I. Prosvirin and L. F. Chernov. (*Vestnik Mashin.*, 1957, (8), 70–72). The greatest brittleness of the steel EI 673 during the dispersion of the solid solution between 650 and 1100° occurs at the beginning of the dispersion, and the development of brittleness is accompanied by changes in the resistance and plastic properties of the steel.—L. H.

Survey of Possible Wear Mechanisms. J. T. Burwell, Jnr. (*Wear*, 1957, **1**, Oct., 119–141). Adhesive, abrasive, corrosive, surface fatigue and other types of wear are described and equations derived relating material removed or useful life to distance of travel, speed, applied load and mechanical properties. Agreement over certain ranges is good and may be used in design of moving parts.

Practical Wear Testing of Cast Iron. R. B. Whitelaw. (*J. Austral. I. M.*, 1957, **2**, Aug., 54–65). Theories of wear are discussed and field and laboratory methods are considered. The Bundy, Hargreaves, and Lane machines are noted and the use of the Repco machine developed in the author's laboratory is described and compared with metallographic findings, and service and other experience.

Mechanical Properties—A Scientific Approach. M. S. Mitra and G. P. Contractor. *Symposium Organised by the National Metallurgical Laboratory, Jamshedpur, Feb.* 1953. *Publication of Sci. Ind. Res., India*, 1957; 173–178). True stress and true strain are obtained from a tensile test and the existence of a mechanical equation of state is suggested. **Some Aspects of the Flow and Fracture of Metals in Test and Service.** E. H. Bucknall. (179–196). Flow in tensile and impact testing and creep failure, mainly of non-ferrous systems, is reviewed. (34 references). **Factors Influencing the Formation of Flakes in Steel.** H. Shrader and V. G. Pranjpe. (197–221). A comprehensive review of the factors concerned in flaking, mainly due to H_2, and effects of steel making practice, killing and pouring, hot-working, impurities and segregations are considered. **Effects of Austenitic Grain Size and Other Factors on the Brittle Failure of Mild Steel.** B. R. Nijhawan and B. A. Chatterjee. (222–234). A review of metallurgical factors, manganese content, grain-refinement, residual stresses, stress-raisers and similar effects is given. **A Fundamental Approach to the Study and Control of Failures Due to a Liquid or a Brittle Phase Enveloping Grains.** A. A. Krishnan. (235–245). A concept is developed from the phenomena of intergranular penetration. **Stress Concentrations: Their Effect on Design for Repeated Loading.** H. J. Grover and W. S. Hyler. (246–260). Factors in design where stress raisers are unavoidable are discussed. Effects of anisotropy and inhomogeneity, plastic flow and theoretical factors are considered with suggestions for minimizing notch effects. (19 references). **The Influence of Stress Raisers on the Performance of Materials.** N. C. Fick. (261–265). Actual cases of fatigue failure are briefly noted. **Photoelastic Method for Stress Analysis.** C. Broniewska and M. S. Mitra. (266–275). The essential theory is developed. **Investigation of Failures in Aeronautical Engineering.** R. A. P. Misra. (276–286). **Some Aspects of Service Failures at Elevated Temperatures.** A. B. Chatterjee and B. R. Nijhawan. (287–301). Intergranular oxidation, decarburization, carburization, spheroidization, graphitization, carbide precipitation and sigma-phase formation are outlined and recorded failures are discussed. (32 references). **Residual Stress and Its Effect on Service.** B. N. Das and M. S. Mitra. (302–312). The origin of stress and causes of thermal and transformational stresses are discussed and their distribution patterns shown. The effects of different types are considered either in improving or impairing service life. **The Uses of Shot Peening as a Means of Reducing Fatigue Failures in Metal Components.** R. P. McMurrich. (313–331). The effects of the process are shown and equipment and uses are briefly reviewed. Data on enhanced endurance limits are presented. In an appendix, a draft specification for treatment of a typical aircraft component is given. **New Materials of Construction for Heat Engines in High Temperature Service.** B. L. Majumder. (332–338). Ceramics and carbides are surveyed. (36 references). **Some Interesting Engineering Failures Encountered in Australia.** G. G. McDonald. (339–347). A failure of high tensile steel by Pb penetration, brittleness in high speed steel owing to increased secondary hardening temperature, failure of a serrated shaft, light alloy channel failure, fatigue and creep, and failures in sporting weapons and ammunition.

Hardness Testing. A. Lawless. (*Mech. World*, 1957, **137**, Oct., 438–446). A review of basic theories and of the usual methods with a comparison of values. Mohs' scale and scratch tests are mentioned, and Brinell, Vickers, Ludwick, Monotron, Rockwell and the portable meters, dynamic methods and Keep's test are reviewed.

Micro-Hardness Testing. R. Wall. (*Metallurgia*, 1957, **56**, Nov., 259–260; *Iron Steel*, 1957, **30**, Nov., 611–612). The author describes experiences and results obtained in five years of using the micro-hardness testing technique, and discusses the technique both as a laboratory tool and as a production quality control method.—G. F.

Hardness and Other Physical Properties of Metals in Relation to Temperature. E. R. Petty. (*Metallurgia*, 1957, **56**, Nov., 231–236). The author discusses the use of hot hardness testing as a tool for high temperature deformation studies, and reviews the past literature showing the relation of hardness values to many other metallurgical properties. The mode of deformation in the "equicohesive range" is discussed and used to explain the form of the hardness-temperature relationship for pure metals. A simple correlation between hardness and creep properties is shown to exist for a variety of metals.—G. F.

Toughness of High-Carbon High-Chromium Steels. K. Yoshinaga. (*Tetsu to Hagane*, 1955, **41**, Sept., 1042–1044). [In Japanese]. Grinding and blanking data, and curves showing the influence of quenching and temperature on the hardness and bending resistance are given for two steels, for quenching temperatures between 900° and 980° C.—K. E. J.

Influence of Residual Stress on Hardness. P. A. Blain. (*Met. Prog.*, 1957, **71**, Jan., 99–100). The author maintains that true hardness is a measure of resistance to impingement rather than to penetration, and should be expressed as the maximum pressure which can be applied locally without causing plastic deformation. He demonstrates that hardness is not only affected by material analysis and state of heat-treatment or cold-work, but also by the direction and magnitude of residual stresses.—G. F.

Studies on the Mechanical Properties of Low-Alloy Steel Castings. S. Miyazaki. (*Tetsu to Hagane*, 1955, **41**, Sept., 978–980). [In Japanese]. Relationships are shown between Shore hardness number and carbon content for Cr-Mo, Mn-Mo and Mn-Cr-Mo steels, given various heat-treatments in each case.

Evaluation of the Hardenability of A.I.S.I. 9255 Steels. R. E. Lamb. (*B.H.P. Tech. Bull.*, 1957, **1**, Oct., 38–45). Silicon-manganese spring steels were examined and related to composition so that hardenability could be calculated for the final hot-rolled section. Fifty samples were submitted to the Jominy test and full details are tabulated and correlated with Si, C and Mn.

Hardenability Bands for Steels 4118-H to T8 4150-H. (*Met. Prog.*, 1957, **72**, Dec., 96B). A series of hardenability diagrams is presented for steels containing 0·20–0·35%Si, 0·75–1·20%Cr, 0·15–0·25%Mo, and ranging from 0·2 to 0·5%C.—G. F.

On the Natural Ageing of Quench-Tempered Steel Wire. M. Tagaya and Y. Soyama. (*Osaka Univ. Fac. Eng. Techn. Rep.*, 1956, **6**, Oct., 308–312). Steel wire 0·3 mm dia and with 0·6%C was examined. Hardness, toughness and electrical resistance change and appear similar to the effects of tempering, which apparently continues at room temperature. To prevent this, careful control of austenizing conditions is needed.

Study of the Wear Resistance of Spheroidal Cast Iron. I. Effects of Graphite Nodule Size on Wear Resistance. T. Takase and K. Nakamura. (*Nippon Kinzoku*, 1956, **20**, Feb., 74–77). [In Japanese]. Irons with large sized nodules have better wear resistance than those with small nodules, in spite of lower hardness, and are recommended for brake shoes of cars.

Friction and Wear Under Boundary Lubrication. B. Lunn. (*Wear*, 1957, **1**, Aug., 25–31). The boundary layer is treated as a plastic solid.

The Use of X-Ray Structure Analysis for Investigating the Sulphiding of Steels. Yu. M. Vinogradov and V. D. Zelenova. (*Zavodskaiya Laboratoriya*, 1957, **23**, (6), 697–699). [In Russian]. It is becoming more and more necessary to be able to superimpose the results of the investigations for friction and wear on those of phase analysis of the surface layers of the sulphided specimens. By using X-ray structure analysis it is possible to determine at the same time the correlation between the increase of resistance to cracks during sulphiding, and the formation on the surface of FeS.—L. H.

The Raising of the Resistance of Stainless Steels to Splitting During Wear, with Lubricant. B. Kh. Somin and S. L. Matskevich. (*Vestnik Mashinostroeniya*, 1957, (3), 28–34). [In Russian]. The problems for investigation were: Establishing the cause of the increased susceptibility of stainless steels to cracking, especially the influence of their chemical composition, and evolving effective methods of eliminating this during wear, on articles manufactured from such steels. This detailed study has considered in turn the influence of lubricants, of the chemical composition, of phosphiding, sandblasting, lacquer covering etc. under most varied conditions of work, under varying temperatures, rates of revolution, friction, stresses etc. Findings are tabulated and accompanied by ample graphical data.

Thermal Aspects of Galling of Dry Metallic Surfaces in Sliding Contact. F. F. Ling and E. Saibel. (*Wear*, 1957, **1**, Oct., 80–91). Seizing of polished surfaces is discussed and a criterion for galling based on thermal aspects of sliding is derived and is valid for dissimilar metals, especially for softer material sliding on harder material.

The Wear of Cast Iron Machine Tool Slides, Shears and Guideways. H. T. Angus. (*Wear*, 1957, **1**, Aug., 40–57). Microstructures, P content, and hardness are examined for slides of 30 tools still in use and optimum requirements are summarized.

Radioactive Isotopes in the Study of the Wear of Machine Parts. D. B. Smith. (*Steam Eng.*, 1957, **27**, Sept., 432–434). A review, including work on tool wear, and studies on drop forging dies.

Investigation of Wear Resistance of Steels in Abrasive Media. M. M. Tenenbaum and V. M. Guterman. (*Vestnik Mashinostroeniya*, 1956, (12), 25–29). [In Russian]. The results of the relation to wear of steel parts, of their hardness, under condition of friction and creep, with lubricants greatly obstructed by abrasives, are summarized as follows.—The resistance to wear grows with diminishing creep, with diminishing content of abrasives in the lubricant and with diminishing applied pressure. With constant chemical composition of the working parts and under equal conditions of friction their resistance grows with the increase in hardness and with the increase of the carbon content in the surface layer.—L. H.

Wear in Cylinder Liners. K. Fursund. (*Wear*, 1957, **1**, Oct., 104–118). Wear from seizure, from contact between surfaces through loose particles, and wear from fixed, projecting elements are distinguished microscopically. Highly concentrated H_2SO_4 is shown to condense during running in Diesel engines.

Study on the Mechanism of Slide Wear. II. K. Ogawa. (*Nippon Kinzoku*, 1956, **20**, Feb., 71–74). [In Japanese]. The wear of austenitic steel was studied. As compared with normal steel, it has better thermal and corrosion resistance, and resists dry wear better; its resistance to lubricant wear, however, is less

than that of steels having higher room-temperature hardness. High-Mn steel is very tough; deformation at the worn surface produces γ and ϵ phases which transform to martensite, increasing the wear resistance. The amount of wear decreases with increase in hardness, even when the hardness is produced by the working stress.—K. E. J.

Permissible Stresses for the Steel-Textolite Friction Pair in Infinitely Variable Gears. (*Vestnik Mashin.*, 1955, (1), 29–32). [In Russian]. The permissible stresses are worked out for Textolite antifriction material in gears of the various tools used in the U.S.S.R.—L. H.

Advances in Nondestructive Test Methods. (*Met. Prog.*, 1957, **72**, Oct., 143–144, 222, 224). Tests on tubes for a nuclear reactor are considered. The latest devices are outlined including polariscopic examination by reflexion from a plastic sheet cemented to the part.

The Relative Advantage and Limitation of Nondestructive Testing Methods. L. van Ouwerkerk. (*Nondestr. Test.*, 1957, **15**, Sept.-Oct., 298–312). A review of radiographic, ultrasonic, magnetic particle and penetrant methods. Gamma and X-ray methods are surveyed by the author and a note on restrictions of radiography with high energy is added by H. den Hartog. The calibration of equipment is considered by G. Moravra, considering radiation quality and quantity and photographic and dosimetric methods of measurement. Ultrasonic inspection of welds is reviewed by A. de Sterke with reference to shear wave probes and welds in thin plates; the same author writes on magnetic and penetrant methods. Other notes are added by B. Schuil and A. Junghem.

Colour Defectoscopy. N. V. Khimchenko. (*Zavodskaya Laboratorya*, 1957, **23**, (7), 803–806). [In Russian]. Because of its simplicity under workshop conditions, the method has been studied and greatly improved during 1955 at the Institute of Chemical Machine Constructions, so that it now replaces the X-ray and gamma-radiation methods. The colouring-fluid recommended consists of 80% kerosene, 15% transformer oil, 5% turpentine, 10 g Sudan III to 1 l. solution. A full description is given and claims to its high efficiency are supported.—L. H.

The Non-destructive Testing of Wire Ropes and In Particular Winding Ropes by a Magnetic Method. Y. Verwilst and J. Strobelle. (*Rev. Mét.*, 1957, **54**, Aug., 611–616). A method is described for the magnetic testing of wire ropes which has been found very satisfactory in Belgium and enables the detection of any deterioration. This method has formed the subject of official regulation issued by the Belgian Administration of Mines.—B. G. B.

Determination by the Induction Method of the Thickness of Hardened Layers. M. A. Kotkis. (*Zavodskaya Laboratoriya*, 1957, **23**, (7), 819–821). [In Russian]. This magnetic method allows a simple and sufficiently accurate determination of the thickness of the hardened layers without the rupture of the specimens. It is based on the ratio between the induction difference of the non-hardened specimen with layers of unknown thickness and the layers of the hardened specimen, over the induction difference between the non-hardened specimen and a hardened standard specimen. The tabulated results of these measurements justify the claims made by the authors in support of this procedure.—L. H.

The Mystery of Magnetic Annealing. J. J. Becker. (*Metal Progress*, 1957, **72**, Aug., 84–89). A review of the basic principles of magnetism and magnetic alloys is first presented. The properties of some magnetic materials are improved by annealing in a magnetic field and possible explanations for this are given.—B. G. B.

The Effect of Magnetic Annealing and Perminvar Character in Ferromagnetic Solid Solutions. M. Yamamoto and S. Taniguchi. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 127–131). [In Japanese]. Ferromagnetic uniaxial anisotropy induced by magnetic annealing in solid solutions can be explained by the anisotropic coupling between atom pairs caused by the interplay between spin-orbit coupling and orbital valency. When the ferromagnetic solid solutions are annealed in the absence of a magnetic field, every domain wall is stabilized by this induced uniaxial anisotropy, which leads to the Perminvar character. (13 references).—K. E. J.

Fundamental Research on Constant-permeability Alloys. I. The Cause of Perminvar Characteristics of the "Senperm" Alloys of the Fe–Ni–Si System. S. Takeda, Y. Iwama, and T. Muramoto. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 123–126). [In Japanese]. The constitution of alloys containing 15 at.-% Ni and 5–25 at.-% Si, balance Fe, was investigated by various means. No superlattice is formed, but a ferromagnetic ternary compound (α-phase) is precipitated from the ϵ-phase. The striking magnetic characteristics are obtained when this is precipitated as a disperse phase, e.g. by furnace cooling from 900° C.—K. E. J.

A Whole Sheet Testing Apparatus for the Grading of Transformer Sheets. A. Fiebiger. (*Siemens-Zeitschrift*, 1956, Sept., 543–548; Translation T.S. 680). Previous instruments are reviewed and a magnetic device is described and its values given and interpreted.

On the Wiedemann Effect in Iron–Aluminium Alloys at High Temperatures. Y. Shirakawa, T. Ohara, and T. Abe. (*Nippon Kinzoku*, 1956, **20**, Feb., 81–84). [In Japanese]. The effect (torsion caused by a circular magnetic field due to a current through the specimen and a longitudinal field) is investigated in thirteen alloys. As Al is added to iron, the effect reaches a maximum at 13% Al. In alloys containing less than 6% Al at high temperature, the effect is similar to that in iron; in the others it is similar to that in Alfer.

The Effect of Impurities in Steel on the Magnetic Reversal Losses in Hot-Rolled Transformer Plate. T. Brüggemann. (*Neue Hütte*, 1957, **2**, July, 404–409). Impurities in connection with this problem are listed as the accompanying minerals in the iron and all the gases, oxides, or sulphides present in the iron–silicon alloy or Fe–Si–Al alloy, or liable to be formed in the transformer plate during processing. Intensive boiling of the steel is necessary to reduce the accompanying minerals, care being taken to remove the oxygen introduced before the steel is alloyed with ferro-silicon or Al.—L. J. L.

The Application of Thermomagnetic Analysis to the Study of the Transformation Characteristics of Iron Materials Between − 150 and + 1500° C. R. Kohlhaas and H. Lange. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 645–653). It is shown how thermomagnetic analysis can be extended to temperatures up to 1500° C. The magnetic characteristics of iron and iron alloys are described. Magnetic measuring methods can be applied to paramagnetic states of iron alloys at high temperatures by using the vacuum chamber of the measuring instrument as a positive pressure chamber, thus suppressing the evaporation of metal atoms into the furnace.—L. J. L.

On the Problem of the Magnetic Ageing of Soft Steel. W. Matz and W. Peter. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 655–662). Statistical evaluation of a large number of unkilled O.H. steels from current production has shown that N, O, and, to some small extent, S increase magnetic ageing. Mn and Cr have the opposite effect. The P and C contents encountered in practice have no effect.—L. J. L.

Creation of Magnetic Texture by the Magnetic Field in Thin Layers of Iron Obtained by the Electrolytic Method. N. V. Kotel'nikov. (*Doklady Akad. Nauk S.S.S.R.*, 1957, **113**, (1), 97–99). A uniaxial magnetic field with its axis in the direction of the applied field was produced. As shown by X-ray study the magnetic texture is not crystalline but is determined by internal stress. Marked influence is shown by the nature of the surface upon which the thin layer is deposited. Numerical data relating to the energy and stresses are also given.—S. I. T.

The Preparation and Magnetic Properties of High Purity Raney Iron. W. D. Johnston, R. R. Heikes, and J. Petrolo. (*J. Am. Chem. Soc.*, 1957, **79**, Oct. 20, 5388–5391). Raney metals are prepared by solution of their Al alloys in alkali. Iron of 95% purity was produced and the particle shape estimated from magnetic data.

Measurement of Elastic Stresses With The Aid of The Magneto-Elastic Effect. G. Bubenzer. (*V.D.I.Z.*, 1957, **99**, Sept. 1, 1215–1217). An investigation by Scheuhle is summarized, in which changes of coercivity and permeability with mechanical stresses were studied. With a suitable choice of frequency and magnetizing current the effects of composition and structure of the material were eliminated. There are, however, difficulties about the calibration zero owing to the uncertainty about freedom from residual stresses in the specimen.—J. G. W.

The Influence of Technological Factors on Electromagnetic Properties of Cold-Rolled Transformer Steel. M. M. Ioffo, A. G. Petrenko, and G. F. Chub. (*'Stal'*, 1957, (10), 936–940). Effects of C and Si, of vacuum treatment of the steel and the temperature of vacuum annealing were examined.

Automatic Inspection of Billets by Electromagnetic and Ultrasonic Methods. V. Husarek. (*Stahl u. Eisen*, 1957, **77**, Oct. 17, 1483–1487). The author describes the techniques employed in ultrasonic testing by the impulse-echo method, and electromagnetic inspection with 7000 c/s of wire bars at IRSID and discusses the advantages of a combination of the two methods of inspection for a fully automatic plant.—E. G.

On the Conductivities of Some Ferrous Materials. K. Löhberg and J. Motz. (*Giesserei*, 1957, **44**, May 23, 305–308). A review of the literature indicates the manner in which solid solutions of various elements with pure iron reduce its electrical and thermal conductivity. The manufacture of ten specimens of steel and cast iron alloys, with spheroidal to lamella graphite formation and the measurement of their thermal and electrical conductivity is described. The results are discussed in terms of the higher thermal conductivity and larger electrical resistance of graphite compared with iron, and its geometrical configuration.

The Use of Ultrasonics. J. L. Pignet. (*Rev. Mét.*, 1957, **54**, Oct., 737–755). Fatigue crack detection is discussed and then the difficulties of interpreting results from forged and cast objects. General conclusions are summarized.

Ultrasonics in Industry. H.-J. Martin. (*Technik*, 1957, **12**, Oct., 669–678). The applications of ultrasonics in physical, chemical, metallurgical, and medical processes, in non-destructive testing, echo-sounding, and electrolytic polishing, are painstakingly catalogued and briefly discussed.—L. J. L.

Ultrasonics in Technology. H.-J. Martin. (*Technik*, 1957, **12**, Sept., 607–611). Recent developments in ultrasonics are surveyed including generation and fundamentals of the behaviour of ultrasonic radiation.—J. G. W.

Industrial Applications of Ultrasonics. J. Palmé. (*Mém. Soc. Ing. Civils France*, 1957, **110**, May-June, 174–193). A general review of the use of ultrasonics not only in non-destructive testing of metals but also in degreasing, dust cleaning, soldering, grain refinement during metal solidification, and chemical reactions is presented.—B. G. B.

Automatic Ultrasonic and Magnetic Testing of Thin Plate and Sheet. L. Beaujard. (*Bull. Cercle Etudes Mét.*, 1957, **7**, Sept., 187–223). A comprehensive review of ultrasonic and magnetic testing is presented. A wide range of techniques is considered.—B. G. B.

Attenuation of Ultrasonic Waves in Metals. III. Attenuation in Chromium–Molybdenum Steels. T. Hirone and K. Kamigaki. (*Nippon Kinzoku*, 1954, **18**, Mar., 185–188). [In Japanese]. Measurements were made on specimens quenched from 1000° C and annealed at various temperatures between 100° and 680° C. The attenuation constant is smaller for martensitic structure than for pearlitic, and even less for troostite. These changes are explained in terms of Rayleigh scattering of the waves by the various structures. **VI. Flake and Nodular Graphite Cast Iron.** (1955, **19**, Feb., 92–94). [In Japanese]. Attenuation in grey iron containing approx. 3·5% C and 2·0% Si rose rapidly with increase of frequency above 0·5 Mc/s and with the

size of flake graphite. The work indicates scattering of the waves by elastically anisotropic pearlite grains separated by flake graphite. The quantitative value of the anisotropy agrees with that of hypo-eutectoid steel.—K. E. J.

Uses of Statistical Methods for Ultrasonic Inspection Problems. M. J. Bratt. (*Nondestr. Test.*, 1957, **15**, Sept.-Oct., 282–287). Analysis of data on typical problems is shown to illustrate the value of statistical methods in engineering problems.

The Diffusion of Hydrogen in Steel at Temperatures of − 78° to 200° C. J. D. Hobson. (*J.I.S.I.*, 1958, August, 315–321). [This issue].

Effect of Titanium and Zirconium on the [Resistance to Sulphurisation] of Cast Iron at High Temperatures. H. Nakai. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 991–993). The effects are studied through loss-in-weight measurements, spectral analyses and micrographs. The losses in weight show apparent minima for a Ti content of 1·17% and a Zr content of 1·85%.—K. E. J.

Behaviour of Nitrogen in 3% Silicon Iron. F. E. Fryxell, N. Galitzine, and F. S. Gardner. (*J.I.S.I.*, 1958, August, 327–332). [This issue].

Stainless and Heat Resisting Steels, June 1957. (*A.I.S.I. Supplementary Information*, 1958, Feb. 1 p.). A Cr-Ni-Mo steel, D319 is added to the list for service in the chemical industry.

Mechanical Properties of E.I. 579 Steel After Prolonged Heating at 550 and 700° C. E. I. Uryupina. (*Metallov. Obrab. Met.*, 1956, (3), 52–55). E.I. 579 steel contains C 0·19, Si 0·2, Mn 0·41, S 0·017, P 0·014, Cr 2·37, Ni 0·10, W 0·46, Mo 0·4 and V 0·85. Its secondary phase is VC. When the quenched steel is heated to 550 to 700° C for a prolonged period, its properties constantly change. The tensile strength and yield point are reduced, reduction of area and elongation are increased at 700° C and undergo a slight reduction at 550° C. Impact strength is somewhat increased at first and then diminishes.—R. S.

Tool Steel Development. A. P. T. Taylor-Gill. (*J. B'ham. Met. Soc.*, 1958, **38**, Mar., 3–26). A review of structures, properties, heat-treatments, compositions and other topics is given.

Improving the Composition of Tool Steels. Yu. A. Geller. (*Metallov. Obra. Met.*, 1955, (3), 1–16). The compositions of a large variety of steels have been considered in relation to the effects they have regarding the properties required of the respective steels. The types investigated included carbon and alloy steels, carbon steels with low alloy elements, alloy steels for metal cutting tools, for woodworking machinery, high-speed steels, tool steels, steels for stamping and for cold-working, steel for instruments, etc.

The findings are given graphically and tabulated.—L. H.

On the Superiority of Mn-Cr Spring Steel. M. Uchiyama. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1059–1061).—K. E. J.

Spring Steel with High Relaxation Properties. T. I. Volkova. (*Metallov. Obrab. Met.*, 1956, (12), 12–16). Relationships are discussed between the basic criteria of relaxation and initial stress and testing temperature. Both laboratory and production data are used.—R. S.

Nickel and Its Alloys. J. G. Thompson. (*N.B.S. Circular* 592, 1958, Feb. 5, pp. 87). This supercedes Circular 485. Ferrous alloys are reviewed (pp. 35–61). Nickel steels, structural steels, cast steels and cast irons, austenitic Cr-Ni steels, super alloys, thermal-expansion alloys and magnetic alloys are all reviewed, their relevant mechanical and corrosion-resisting properties are given, and their uses indicated.

Studies on Nickel-base Heat-resisting Alloys. III. T. Hasegawa. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1009–1011). The effects of various specified heat-treatments on the stress-rupture properties at 750° C and 816° C and the tensile properties of alloys containing approximately 56%Ni, 19%Cr, 10%Co and 10%Mo (analyses given) are examined. **IV.** (1011–1013). Results of tests on Nimonic 80A show the effects of ageing and heat-treatment on stress-rupture characteristics at 750° C and 26·8 kg/mm², and also their effects on tensile properties at room temp. and 750° C.—K. E. J.

Avesta Stainless Steels 664M and 664MV. Acciaieria di Avesta. (*Acciaio Inossid.*, 1957, **24**, Sept.-Dec., 146–149). [In Italian]. The scarcity of Ni has led steelmakers to find alternative alloying elements which will give steel corrosion resisting properties at least equal to the traditional high nickel-bearing steels. Research led Avesta to find a steel with excellent stainless properties with the following approximate analysis: C = 0·09%; Mn = 7%; Ni = 4·5%; Cr = 17%; N = 0·15%. Variants of this steel are discussed.

A New Steel for Hot Airplanes and Missiles. M. E. Carruthers. (*Steel Proc.*, 1958, **44**, Jan., 19–23, 50–51). A precipitation-hardening steel with 15%Cr and 7%Ni known as PH 15-7 Mo is described. The steel has an austenitic grain structure and is weldable without susceptibility to cracking. Comparisons of mechanical and creep properties are made with other steels and with light alloys.

Tool Steels for Aircraft. L. V. Klaybor. (*Steel Proc.*, 1958, **44**, Jan., 16–18). The high-temperature properties of a range of tool steels are surveyed with a view to their use as skin materials in high-speed aircraft. The properties of Potomac M appear to be particularly well adapted to the purpose.

Investigations of Properties of EI 723 (TsZh-4) Steel (CrMoV). Z. N. Petropavlovskaya and V. Z. Tseitlin. (*Metallov. Obrab. Met.*, 1956, (12), 17–27). The effect of alloy elements on relaxation properties of CrMoV steels are studied.—R. S.

METALLOGRAPHY

Some Trends in the Future Development of High Temperature Metallography. M. G. Lozinskii. (*Izvest. Akad. Nauk. Otdel.* 1957, (11), 14–26). After a brief account of the development of this branch of research, a new apparatus is described, IMASh-5 M, evolved under the direction of the author. The method of working is explained and diagrams tabulating results of investigations are given.—L. H.

Ferrous Metallographic Practice. P. C. Rosenthal. (*Trans.A.F.S.*, 1956, **64**, 709–718). A review with numerous illustrations is presented of the metallography of steel, malleable iron and cast iron for foundry purposes.

On Hot-stage Microscopy—a Review. T. Akutagawa and T. Bada. (*Tetsu-to-Hagane*, 1957, **43**, Oct., 1143–1152). The development of hot-stage microscopy from 1909 onwards is reviewed, and future applications are discussed. A new type of microscope with a 16 mm ciné-camera, and a vacuum-heating stage are described; results from these are given, to throw light on the martensite and bainite transformations of Ni-Cr-Mo steel and creep-rupture phenomena. (23 references).

The Electron Microscope. II. D. A. Senior. (*Inst. Practice*, 1957, **11**, Nov., 1162–1165). Preparation of specimens, types and uses of electron microscopes, diffraction methods, calibration of magnification and a brief survey of modern instruments are included. Future possibilities are touched upon.

Observation of Metal Sections by Means of the 300-kV Electron Microscope. H. Tsuchikura and K. Ichige. (*Nature*, 1958, **181**, Mar. 8, 694–695). Cutting of thin sections of steel and other metals has been carried out and diffraction patterns are shown.

Electron Microscope and Diffraction Studies of 7% Chromium-Molybdenum Steels. B. E. Williams. (*Brit. J. Appl. Phys.*, 1957, **8**, June, 241–247). An examination of 7%Cr–2%Mo creep-resisting steels with a view to improving their strength is reported. Finely divided TiC was observed in samples showing good creep resistance. Heat treatment is somewhat critical.

Microscopical Investigation into the Growth of Cracks and Fractures. S. N. Zhurkov and E. E. Tomashevskii. (*Zhur. Tekn. Fiz.*, 1957, **27**, (6), 1248–1256). [In Russian]. Experiments were made on specimens 1–2 mm long and 20–50 microns in thickness. Each experiment related to one single crack, in a specimen subjected to a constant stress along a single axis. The materials were cellulose acetate foils from polycrystalline zinc, aluminium and also lamina of silicate glass. It has been found that the growth of the crack proceeds with increasing rapidity up to rupture. This progress has been filmed.

The Utilisation of Chemical Polishing for Metallographic Purposes. P. Slyško. (*Zvar. Sbornik*, 1957, **6**, (4), 462–488). [In Slovak]. Theoretical and practical aspects of chemical polishing are surveyed. Conditions suitable for chemically polishing and etching a number of metals and alloys, particularly those formed in brazing, are given.—P. F.

Revealing Austenite Grains by the Method of Anodic Etching at High Temperatures. Z. Wojcik. (*Prace Inst. Ministerstwa Hutnictwa*, 1957, **9**, (4), 141–150) [In Polish]. The author discusses different methods of revealing austenite grains and the process of electrolytic polishing at high temperatures.

He describes a new method of revealing austenite grains based on anodic etching at 800° C conducted in molten lithium chloride. Trials of this method were carried out with 8 grades of steel and showed satisfactory results.

Comparison of Two Methods of Preliminary Isolation of Inclusions of Oxides in Low-Carbon Steels by Electrolysis. J. Foryst, J. Orzechowska and W. A. Mazedliszwili. (*Prace Inst. Ministerstwa Hutnictwa*, 1957, **9**, (4), 161–165.) [In Polish]. A description of Klinger's and Koch's (which is an improvement on Treje and Benedict's), and Fitter's (improved by Lukasiewicz-Duwan, Leue and Szapiro) methods are given. Results of preliminary isolation of inclusions obtained by the two methods were compared and it was found that, applied to a non-alloyed steel, they were in good agreement.

Study on Carbides in Commerical Special Steels by Electrolytic Isolation. VII. On Carbides in High-Speed Steels. I. T. Sato. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1069–1071). The compositions of the carbides and matrices in 18–4–1, 11–4–2, 11–4–5 and 5–4–5 steel (analyses given) are examined under various conditions of heat treatment.—K. E. J.

On the Method of Investigating Sulphide Inclusions in Steel Castings. K. I. Basov and M. I. Mnogolet. (*Lit. Proizv.*, 1955, (8), 20–21). [In Russian]. The specimens were heated in laboratory muffle furnaces up to 870°, cooled in the furnace to 750° at the rate of 1°/min and then quenched in cold water. On these specimens, polished surfaces were prepared in the usual way and etched with a 3% solution of HNO_3 in alcohol. The method eliminates the necessity for careful polishing and facilitates photography. Good results can also be obtained by the preparation of specimens isothermally.—L. H.

The Composition and Physical Chemistry of Inclusions in Chromium-Bearing Irons. R. Zoja, L. Benussi and M. Caveri. (*Chim. e Ind.*, 1958, **40**, Jan., 1–5). [In Italian]. The authors describe the determination of non-metallic inclusions in chromium-bearing irons by means of anodic action. In particular they have studied their chemical composition in the α- and β-phases and they have been able to show, by means of X-ray analysis, that these are non-crystalline. The α-phase is a silicate with about 75% SiO_2 and 20% Cr_2O_3, quite transparent and completely colourless (petrographic microscope). But the β-phase contains only 35% SiO_2 and 60% Cr_2O_3 and is opaque. The phases are two solutions resulting from the mixture of monophase inclusions present at the melting temperatures of the chromium-bearing iron.

On Segregation of Chemical Elements in Large Cylinder Liners. K. Hojyo. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 994–995). The study is concerned with the distribution of total C, graphitic carbon Si and P and of Brinell hardness.—K. E. J.

Study on the Banded Structure of Cr-Mo Case-hardening Steel. T. Muraji. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 901–903).—K. E. J.

Recrystallisation of Iron. (*Can. Mines, Research and Special Projects Report*, 1957, July-Dec., 23–24). Etch-pit studies are reported and a strain-anneal technique for control of orientation has been examined.

Precipitation of Carbon in Alpha Iron. (*Can. Mines, Research and Special Projects Report*, 1957, July-Dec., 26–27). Electron microscope studies have been conducted on specimens treated in a special furnace.

CORROSION

Economic Aspects of Corrosion. A. Keynes. (*Chem. Ind.*, 1958, Apr. 5, 398–400). Construction of histograms for "corrosion-proneness" of equipment in various industries is discussed. The economic balance between the use of resistant materials and cathodic protection is also considered.

Corrosion and Preservation of Gas Works Plant. L. A. Ravald. (*Trans. Inst. Gas Eng.*, 1953–4, **103**, 286–322).

Dissolution of Metals, Particularly Iron and Mild Steel, In Acid. T. Hurlen. (*Tek. Uke.*, 1958, **105**, Feb. 6, 119–122). The author continues to follow his theme on the corrosion of ferrous metals of the type that evolves H_2 and finally sums up. (28 references).

Action of Modern Detergents on Hot-Galvanised Coatings. H. Bablik and M. Belohlavy. (*Werks. Korr.*, 1957, **8**, Dec., 742–746). Corrosion tests show that hot-galvanised steel does not stand up to attack by modern detergents containing polyphosphates. Consequently, washing machines in which such detergents will be used should be built of more corrosion-resistant materials.

On the "Below Dew-point" Type of Corrosion. II, III. Boiler Corrosion. S. Jo. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 1077–1079; 1079–1080). —K. E. J.

On the Effect of Permeability of Oil Films to Water Vapour on the Corrosion of Steels Protected by Oil Layers. R. Bartoníček. (*Chem. Listy*, 1957, **52**, (2), 190–195). [In Czech]. Details of researches on the protection afforded by various oils, greases and oil-grease mixtures are given and discussed. The necessity for adding inhibitors to the oils to render them suitable for protection of steels is emphasized, and the mode of action of the inhibitors is considered.—F. F.

Oxidation of Metals. W. W. Smeltzer and L. H. Everett. (*Ind. Eng. Chem.*, 1958, **50**, Mar., Part 2, 496–502). A general review for 1957. (199 refs.).

Influence of Uniformity on the Oxidation of Alloys. J. W. Evans and S. K. Chatterjee. (*J.I.S.I.*, 1958, August, 332). [This issue].

Kinetics of Intercrystalline Corrosion of Chromium-Nickel Stainless Steels. V. Sh. Shekhtman, M. A. Vedeneeva and N. P. Zhuk. (*Zhur. Fiz. Khim.*, 1954, **28**, (12), 2199–2210). [In Russian]. A solution of NaF 9 g/l in 20% HNO_3 was used. It is claimed that this etching fluid, even without heating, acts 10/15 times faster than the standard solution of $CuSO_4 \cdot 5H_2O$ and H_2SO_4. The experimental data obtained explain the theory behind the tendency of certain steels to intercrystalline corrosion between 500° and 800° C all along the carbide grains, along grains rich in Cr and also along grains in regions of the solid solution poor in Cr.—L. H.

Mechanism of Corrosion Cracking of Austenitic Steels. A. V. Ryabchenkov and V. M. Nikiforova. (*Metallov. Obra. Met.*, 1956, (8), 2–11). The main reason for the reduction in potential under stress is micro-cracking which occurs in the protective oxide film. The displacement of the total electrode potential into the negative field caused by stress is not an index of the tendency to corrosion cracking. In steels prone to corrosion cracking, there is a distinct difference in potential between the separate micro-particles under stress corrosion conditions and it is this difference in potential which is the main cause.—E. E.

Stress-Corrosion Cracking of Austenitic Stainless Steels. T. P. Hoar and J. G. Hines. (*Chem. Ind.*, 1958, Apr. 5, 404). Two stages were distinguished by studies of wire in hot $MgCl_2$ solution, an induction period of crack formation and a period of propagation.

Stress-Corrosion Cracking of Carbon and Low Alloy Steels. R. N. Parkins. (404). The effects of carbon content and carbide distribution and the formation of ferric nitrate in the cracks is described. Alleviating treatments are mentioned.

Fretting Corrosion and Fatigue Failure. C. E. Phillips. (*Teks. Uke.*, 1958, **105**, Mar. 27, 281–286). [In English]. A study on screw threads is reported. The mechanism is discussed and methods of prevention are suggested.

A Bibliography of Literature Relating to Fouling and Its Prevention. (*Admiralty Centre for Scientific Information and Liaison*, 1956. pp. 236). 1942 Titles in alphabetical order of authors are given.

Cathodic Reduction of Oxide Films on Iron. II. Determination of α-Fe_2O_3 and Fe_3O_4. K. H. Buob, A. F. Beck and M. Cohen. (*J. Electrochem. Soc.*, 1958, **105**, Feb. 74–78). Weight change, electron and X-ray diffraction and chemical analysis were used to examine oxide films. Evidence was found for a thin layer of γ-Fe_2O_3 between the Fe_3O_4 and α-Fe_2O_3. Accurate measurements can be made by cathodic reduction.

The Corrosion Resistance of Tin Alloy Electrodeposits. F. A. Lowenheim. (*Proc. Ann. Conv. Amer. Electroplaters' Soc.*, 1957, 42–46; discussion 160–161). Sn undercoats, Sn-Zn, Sn-Cd, Sn-Pb, Sn-Ni, Sn-Cu are discussed and exposure test results are given. (35 refs.).

Diffraction and Electron Microscope Study of Natural and Artificial Oxidation Films Formed on Pure Tin and On Tin Plate. J. J. Trillat, L. Tertian and S. C. Britton. (*Métaux-Corrosion-Indust.*, 1957, **32**, Dec., 475–481). Oxide films produced by heating in air at different temperatures and times have been studied and compared with those produced artificially by chemical and electro-chemical methods. The differences in structure which have been observed are discussed.—B. G. E.

Corrosion of Cooling Installations in Refineries. M. Prillieux. (*Corros. Anticorros.*, 1957, **5**, April, 128–130). The author describes tests carried out in order to find the reason for cracks in condensers. These were found to be caused by the low oxygen content of the river water used for cooling. Aeration of the incoming water is not a sure remedy.—R. P.

Cargo Space Corrosion in Tankers. W. G. Richards. (*Tek. Ukeb.*, 1957, **104**, Oct. 24, 869–874). [In English]. Mechanism of corrosion in black petroleum and white oil carriers is outlined, and protection by design and the use of special materials, operating practice, protective coatings, cathodic protection, dehumidification, and the use of inhibitors are reviewed.

Failures of Metals in Sulphur and Sulphur Bearing Media. R. M. Krishnan, P. K. Gupte and B. R. Nijhawan. *Symposium Organised by the National Metallurgical Laboratory, Jamshedpur, Feb. 1953. Publication of the Council of Sci. Ind. Res., India*, 1957; (117–136). Factors such as humidity, temperature and stress are considered and service failures are described. Protection by Cr or Al and the choice of more suitable metals are discussed. (37 references). **The Eight Forms of Corrosion and the Corrective Measures.** M. G. Fontana and M. S. Mitra. (137–148). The eight forms are general and intergranular corrosion, pitting, galvanic or bimetallic and concentration cell corrosion, dezincification, erosion-corrosion and stress-corrosion. These are briefly outlined and illustrated and the ordinary protective measures are listed. **Some Service Failures Arising from Various Types of Corrosion.** R. F. Cotton and A. W. Franklin. (149–154). Examples of failures of a welded stainless steel tank by weld decay and of stainless steel bubble caps by stress corrosion are given, and non-ferrous examples. **Corrosion and the Failure of Metals.** G. E. Gale. (155–165). Mechanisms are outlined and actual cases mentioned. **Corrosion in Boilers and Water Circulation Systems with Special Reference to Marine Installations.** G. E. Gale. (166–172). Pitting, caustic embrittlement and deposit attack are considered.

Corrosion Engineering Research: 2. The Corrosive Action of Soluble Cutting Oils. (*Corros. Prev.*, 1957, **4**, Oct., 55–56). The results of investigations by the Production Engineering Research Association are briefly discussed. In general, clear soluble oils showed less corrosive effect than milky soluble oils. There were notable exceptions (not detailed). The use of distilled water for preparing the emulsion, in place of town's water, appeared to give a slight but inconsistent decrease of corrosion. It was also found that the corrosion activity depended largely on the combined action of metal chips plus emulsion and that a stable emulsion alone caused little or no corrosion on the cast iron surface.—L. E. W.

Some Remarks on the Life and Corrosion of Mine Ropes. J. Teindl and E. Hila. (*Uhli*, 1957, **7**, (10), 325–330). The effects of various metallurgical factors on wire ropes, especially on the cores, are considered and various protective measures such as zinc coating are described. Examples of corrosion are shown, and collaboration between the makers, the mining industry and the research departments is advocated.

Corrosion of Buried Cast Iron. (*Metaalinstituut TNO Publ. No.* 48, Nov., 1956). [In Dutch]. **25 Years Existence of the Corrosion Committee II.** K. W. H. Leefling. **The Discovery of Anaerobic Corrosion of Buried Metals.** C. A. H. von Wolzogen Kuehr. **Asphalt Bitumen.** J. van den Berge. **Practical Results of the Corrosion Committee's Activities.** J. E. Carrière. **Views on Soil Corrosion due to the Presence of Stray Currents.** B. H. Wijngaard and J. W. Boon. These papers form contributions submitted on the 25th anniversary of the Corrosion Committee's existence.—F. B. H.

Inhomogeneity in the Soil and Its Variations in Composition as a Cause of Corrosion. T. Markovic. (*Zaštita Mat.*, 1955, **3**, Jan., 3–4, 12). A cell Iron–Soil I–Soil II–Iron is discussed and the e.m.f. shown to depend on aeration of the soil.

The Corrosion of Buried Metal Ducts. L. Boubela and M. Radomil. (*Paliva*, 1957, **37**, (8), 264–269). [In Czech]. The origin of corrosion in pipes and ducts buried in the soil is discussed, and the most appropriate remedies in the various types of attack are considered in the light of recent developments.—F. F.

Causes and Prevention of Corrosion in Tar Stills. D. McNeil. (*Corrosion Techn.*, 1957, **4**, Nov., 385–389). The author reviews the relevant investigations carried out during the past 25 years and then presents briefly the results of recent investigations by the Coal Tar Research Association. The tests showed that the agents corrosive to mild steel in crude coal tar are of two types: (*a*) inorganic salts dissolved in the liquor associated with the tar and (*b*) phenolic compounds boiling above 240° C. Of the inorganic constituents, ammonium chloride is the most aggressive. In certain continuous retorts, particularly those operated with a high degree of steaming, the inorganic salt content is low and the main attack is due to the higher phenols. The influence of ammonium chloride can be neutralized by the addition of the stoichiometric amount of alkali. The phenolic corrosive agents can be removed by washing the tar with alkalis or by the addition of ferrous oxide. Finally, the author enumerates those metals which, in combination with chemical and physical preventive methods, are the most corrosion-resistant.—L. E. W.

Quantitative Comparison of Surface Finishes and Heat Treatment of Stainless Steel with Respect to Corrosion by Jet Fuels. R. G. Carlson. (*Corrosion*, 1957, **13**, Oct., 672–676). Hardened and tempered free-machining AISI 440C steel was tested after grit blasting, liquid honing, ball burnishing, grinding, and SiC blasting. JP-4 fuel and water was used and weight losses measured. Conclusions are presented.

Corrosion of Material for Plant in Chemical Industries, Especially in the Food Industry. M. Mautner. (*Zaštita Mat.*, 1954, **2**, Apr.,

105–107). Non-metallic substances are included.

Corrosion of Iron in Hydrochloric Acid in the Presence of Inhibitors at Various Temperatures. I. P. Anoshchenko. (*Zhur. Prikl. Khim.*, 1957, **30**, (3), 393–400). [In Russian]. By the polarization-curve method, the influence of potassium bromide, hexamethylenetetramine and acridine and their combinations on electrode processes occurring during the corrosion of iron in 6 N hydrochloric acid solutions at 20, 40, 60, and 80° C was studied. The stationary potential was found to move in the negative direction with increasing temperature, both cathodic and anodic polarizations decreasing appreciably. Hexamine was found to slow down the cathodic solution of iron more at higher temperatures. It was shown that when the three inhibitors were present simultaneously the difference between cathodic potentials at different temperatures decreases with increasing polarization currents. The "nominal activation" energy of the cathodic process was found to decrease with increasing electrode potential. ((4), 523–528). The author describes a continuation of the study of iron corrosion in 6N HCl with the use of volumetric and gravimetric instead of polarization-curve methods. It was found that at 20° C without inhibitors depolarization is effected to over 95% through H+ discharge; with increasing temperature the rate of solution rises geometrically. Confirmation was obtained of the fact that with increasing effectiveness of inhibition the fractional participation of oxygen in depolarization grows. At 80° C the most effective inhibition was shown by a combination of hexamine, acridine, potassium bromide, and methyl alcohol.—S. K.

A Contribution to Potential Oscillations of Iron and Zinc Electrodes in Sulphuric Acid. H. Lüdering. (*Arch. Eisenhütten.*, 1957, **28**, Oct., 625–632). It is shown that the saw-tooth oscillations occurring in the level part of the current density-voltage curve for iron and zinc can be ascribed to the presence of a non-monotonous N-shaped charge density-voltage, characteristic of the surface layer of the electrode.—L. J. L.

Corrosion Problems with Fuming Nitric Acid. M. G. Fontana. (*Corros. Techn.*, 1957, **4**, Dec., 423–424). Use as rocket fuel has raised corrosion problems. Fatigue tests and cathodic protection are discussed. Stainless steels and other alloys were tested.

Intercrystalline Corrosion of Welded Tubes in the Concentration of Nitric Acid. N. A. Bozin. (*Zavodskaya Laboratoriya*, 1957, **23**, (6), 691–692). [In Russian]. The steel examined was IX 18 N T. According to makers' indications the chemical content of Ti and C answered to the formula $5(C - 0{\cdot}03) < Ti < 0{\cdot}08$ so that the steel contained sufficient Ti to combine with the free C. In this way the seam of the tube would not possess the susceptibility to corrosion. The most reliable method of investigation is the boiling of the tubes with a 55–65% solution of HNO_3.—L. H.

Corrosion of Austenitic Stainless Steels in Sulphuric Acid. E. H. Phelps and D. C. Vreeland. (*Corrosion*, 1957, **13**, Oct., 619–624). Steels of AISI Types 304, 310, 316, 317, 321, and 347 were examined in air-saturated and N_2-saturated H_2SO_4 at 30°, 50°, and 70° C. Results are presented in terms of active–passive regions, and the use of potential measurements for detection of corrosion conditions is discussed.

Corrosion and Metal Transport in Fused Sodium Hydroxide. 2. Corrosion of Nickel–Molybdenum–Iron Alloys. G. P. Smith and E. F. Hoffman. (*Corrosion*, 1957, **13**, Oct., 627–630). Measurements were made at 815° C for 100 h. Selective Fe and Mo removal occurs forming subsurface porosity. Compositions > 70% Ni had greater resistance.

Sulphide Corrosion Cracking of High Strength Bolting Material. D. Warren and G. W. Beckman. (*Corrosion*, 1957, **13**, Oct., 631–646). Type 4140 steel bolts were examined in H_2S–H_2O systems at 20–120° C and from 1–17 atm. Cracking susceptibility increased with bolt hardness, increased stress, increased plastic deformation, and decreasing temperature. Annealed Type 316 stainless steel and other alloys were completely resistant. Protective metallic coatings and corrosion inhibitors were tested. The cracking process appears to be due to hydrogen embrittlement.

Corrosion of Metals in Alkaline Solutions. IV. On the Contact Corrosion of Dissimilar Metals. 4. Effects of Electrode Area and Resistance on Corrosion Current. H. Endo and N. Ohtani. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 153–156). [In Japanese]. The corrosion current between zinc and mild steel is expressed as a function of the electrode areas, polarization, radii of anode and cathode, resistivity of the solution and the p.d. The function explains why the observed values of the corrosion current of zinc in Na_2O_2 solutions (pH 7–12·5 at 30° C) undergo changes as the pH varies.—K. E. J.

Electrochemical Properties of Alloys. VI. On the Anodic Behaviour of Iron–Molybdenum Alloys in Sulphuric Acid Solution. S. Morioka and K. Sakiyama. (*Nippon Kinzoku Gakkai-Si*, 1955, **19**, Feb., 157–160). [In Japanese]. Active Fe–Mo alloys containing Mo in solid solution show the same degree of polarization as pure iron, but the critical c.d. at which passivity is attained is higher the greater the Mo content. In polarization of two-phase alloys containing more than 10% Mo, the dissolution of the α-phase and the dissolution of the compound Fe_3Mo_2 are distinguished. By anodic dissolution Fe_2Mo_3 or alloys containing more Mo acquire a protective passive layer of molybdenum blue. Electrode potentials of Fe–Mo alloys are given.—K. E. J.

On the Anodic Behaviour of Nickel. W. Saxer. (*Ph.D. Thesis of the Technical University, Zurich*, 1956, Number 2494, pp. 102). [In German]. The process of passivation was studied in nickel of purity 99·44% and 99·99%.—P. F.

On the Relationship between Natural Electrode Potential and Corrosion Rate. III. S. Shimodairn. (*Nippon Kinzoku*, 1956, **20**, Feb., 93–96). [In Japanese]. A formula is derived for the corrosion resistance of metals in terms of the standard electrode potential and the specific reaction rate constant of the hydrogen electrode. The resistance is apparently related to the work function. General equations for corrosion rate are given in terms of anode film properties, concentration of adsorbed water molecules, the diffusion constant of metal ions and the thickness of the diffusion layer. (14 references).—K. E. J.

Observations on the Physical Appearance of Chemically Attacked Glassed Steel Surfaces. D. K. Priest. (*Amer. Ceram. Soc. Bull.*, 1957, **36**, Nov., 416–418). Borosilicate glass frits on steel were attacked with HCl under reflux and factors in the amount of attack are evaluated.

Corrosion Investigation by Electrical Measurements. D. Hendrickson. (*Corrosion Techn.*, 1957, **4**, Nov., 390–393). The author describes the method employed by the East Bay Municipal District of Oakland, Calif., to determine the cause of corrosion in its large twin-transmission main. Shortly after the second line was built, leaks began to appear in the older aqueduct even though it had been protected by cathodic devices for 15 years. The preliminary electrolysis survey by the potential drop and Hering methods was unsatisfactory and it was necessary to use the Soil Surface-Potential method of survey. This showed that the corrosion in the pipe-line was caused by an electric current discharging electrolytically from the pipe to the soil. The source of the electric current could have been galvanic or from local action, or it could also have been man-made, e.g. a stray railway current.

The Influence of Heat Treatment on the Corrosion Resistance of Stainless Chrome Steels. R. Pospíšil. (*Czech. Heavy Ind.*, 1957, (10), 11–16). The properties and compositions of chrome stainless steels are given and related to the Cr–Ni and Cr–Mn steels and heat treatments and mechanical properties are tabulated. Microstructures showing the effects of incorrect treatment are given. Tests in citric acid are tabulated relating resistance to tempering for 2 h at 200–700° C and finally correct tempering conditions are suggested.

Corrosion Stability of Galvanic Coatings Deposited on a Passivated Surface. L. I. Kadaner and A. Kh. Masik. (*Zhur. Prikl. Khim.*, 1957, **30**, (7), 998–1006). [In Russian]. After discussing some effects produced in the process of the corrosion of plated objects by the presence of a passivated film the authors describe the experimental comparison of the corrosion of plated passivated and non-passivated iron plates. For cathodic corrosion tests, Ni, Sn, and Cu plated specimens were used; for anodic, Zn and Sn plated ones. Passivation was found to increase the resistance to corrosion for all. Passivation gave a more uniform surface, leading to more finely dispersed and less porous deposits. The passive film was found to remain partly on the base metal (in pores).—S. K.

Corrosion Examination of Steel Sheet Piles. G. Stüdemann. (*Stahl u. Eisen*, 1957, **77**, Nov. 14, 1703–1704). Examination of steel sheet piles buried for 20–30 years at the banks and in harbours of inland canals in Germany showed that corrosion was distributed rather uniformly along the length of the piling sheet without the usual increase of corrosion rate at water level. The average corrosion loss was 0·011 mm per year. There was no difference in loss between steels of various composition including plain-carbon basic Bessemer steels.

Description of a New Test Chamber for Corrosion by the AEROSOL Process. W. Hess. (*IVA*, 1957, **28**, (1), 23–35). In testing for corrosion with salt spray it is important that the particles be of the same size so as to get a homogeneous spread. Colloidal dispersal is achieved with Aerosols, and an apparatus for their production and the new test chamber are described. Four methods of testing and the results of experiments follow.

Corrosion Tests Carried Out by the British Iron and Steel Research Association. J. C. Hudson. (*Corros. Anticorros.*, 1957, **5**, April, 119–129). In this final part, the author deals with means of corrosion protection, including paints and metal coatings. Methods of application and variables are discussed.—B. P.

Atmospheric Exposure of Electroplated Lead Coatings on Steel. A. H. DuRose. (*Amer. Soc. Test. Mat. S.T.P.* 197, 1957, 97–106). In some cases a Cu undercoat was used. The self-sealing action of the Pb corrosion products was important.

A Comparison of the Corrosion Behaviour and Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel. C. H. Sample, A. Mendizza, and R. B. Teel. (*Amer. Soc. Test. Mat. S.T.P.* 197, 1957, 49–65). Details of test panel preparation and exposure are given. Humidity and salt spray tests were carried out and the effects are illustrated. In marine, rural, and industrial exposures differences were found which did not correlate with the salt spray test results.

Experiments on Accelerated Corrosion in Sea Water. C. Rekar. (*Rudarsko-Metalurški Zbornik*, 1956, (3), 265–273). [In Serbo-Croat]. Cavitation corrosion of a number of steels was studied in a specially designed tank, the sea water in which was aerated at controllable rates. The increased amount of O_2 in sea water near the shore is shown to be responsible for the increased corrosion rates in such waters. Impurities, particularly copper, appear to favour corrosion of steel under such conditions.—P. F.

A Study of the Resistance to Corrosion and Wear of Aluminised Steels. S. G. Bogdanov. (*Metallov. Obra. Met.*, 1955, (3), 25–31). The thin aluminized layers applied rapidly at low temperatures can be deformed easily in the hot or cold condition and have a satisfactory resistance against: (*a*) corrosion in a 50% HNO_3, in brine vapours, in saturated solutions of picric acid, but not in 50% H_2SO_4 or HCl. (*b*) oxidation at high temperature (900°) even after deformation in the hot condition. Results of analyses carried out at various temperatures for 3–5 h are set out in detail.

Resistance to Corrosion in Stainless Steels. G. Colombo. (*Acciaio Inossid*, 1957, **24**, Sept.–Dec., 133–145). [In Italian]. The influence of various alloying elements on the corrosion resistance of steels is examined. The elements investigated are Cr, Ni, C, Mo, Mn, N, Cu, Si, Al, W, Nb, Ti and Ta.

Inhibition of the Atmospheric Corrosion of Mild Steel by Sodium Benzoate. O. Sarc-Lahodny. (*Werks. Korr.*, 1957, **8**, Dec., 738–742). The results are presented of laboratory experiments and atmospheric exposure tests on the inhibition of the corrosion of steel by sodium benzoate. These support the findings of W. H. J. Vernon, F. Wormwell and colleagues that sodium benzoate is a valuable inhibitor, both when used to impregnate wrapping paper or as an addition to corrosive solutions and cutting oils.—J. C. H.

Centralisation of the Deaeration of Softened Water. G. P. Sutotskii. (*Stal'*, 1958, (2), 185–187). As a result of building centralised deaeration plants instead of local ones, corrosion of water pipes leading from hydro-electric power stations is eliminated and labour is saved in metallurgical plants. Water for all power units is reliably cleaned.—R. S.

Cathodic Protection and Electrolytic Treatment of Water. E. Gasparek. (*Gas World*, 1958, **147**, Apr. 5, *Coking Supp.*, 86–88). Gas cooler protection is described.

Influence of Cathode Polarisation Protection with External Current. L. A. Glikman and L. A. Suprun. (*Metallov. Obra. Met.*, 1955, (6) 10–15). The corrosion medium for these experiments was a 3% NaCl solution. Protectors of Mg alloy containing also 3% Zn, 6% Al and 0·2% Mn are better than zinc protectors. The effectiveness of cathode protection by external current depends on its density and increases with the latter. Anode polarization lowers resistance to corrosion and fatigue.—L. H.

ANALYSIS

Analysis of High-Purity Iron. R. E. Heffelfinger, D. L. Chase, G. W. P. Rengstorff and W. M. Henry. (*Anal. Chem.*, 1958, **30**, Jan., 112–114). Methods for Mn, Cu, Ni, Cr, V, Co, Al, Pb, Ti, W and Zr (spectrographic); the sulphide group; Si, Mg, Ca (by direct arcing) all 0·1–10 p.p.m. B by standard spectrographic methods, C by combustion, S and P spectrophotometrically and O_2, H_2 and N_2 by vacuum-fusion.

New Rapid Method for the Determination of Gaseous Contents in Iron and Steel. IV. Absorption of Gases on Evaporated Metal Films. N. Yoneda. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 949–951). [In Japanese]. Data are given for the velocity of adsorption of CO on samples of Fe, Mn, Al and Si; and for surface areas of powders of these elements as determined by methylene-blue absorption and microscopical examination.—K. E. J.

Gas Content of Magnesium Iron. V. I. Lakomskii and V. I. Yavoiskii. (*Lit. Proizv.*, 1955, (12). 20–22). [In Russian]. The analysis for gases of the iron was carried out by fusion *in vacuo* for the determination of H_2, O_2 and N_2, and by combustion *in vacuo* for H_2 alone. The effect of these gases is studied in connection with the chemical composition of the metal and its microstructure.—L. H.

Sampling of Liquid Steel for Dissolved Oxygen. T. Obinata. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 956–958). Comparisons are made between dissolved oxygen contents obtained with samples killed in the spoon or mould or taken by bomb mould or Rudbery mould. The influence of preheating the bomb mould on the oxygen content obtained is examined.—K. E. J.

Studies on Sampling Methods for Oxygen Analysis of Molten Steel. Y. Nakagawa. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 958–960). The sampling tube is described, and data obtained for the relationship between C and O contents in acid and basic O.H. steel by various methods are compared.—K. E. J.

Further Improvements in the Carbon Cylindrical Type Vacuum-Fusion Oxygen Analyser. Y. Shimokawa. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 954–956).—K. E. J.

Comparative Study on Hydrochloric and Sulphuric Acid as the Dissolving Agent for Determination of the Nitrogen in Iron and Steel. S. Yamasaki. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 951–953).—K. E. J.

Note on the Determination of Carbon by Combustion of Non-Alloy Steels. R. Boulin and E. Jaudon. (*Chim. Anal.*, 1957, **39**, Dec., 463–466). Full details of the apparatus developed are given. CO_2 is absorbed in "Ascarite" (and anhydrone) and weighed.

Determination of Very Small Amounts of Carbon in Metals. R. E. Fryxell. (*Anal. Chem.*, 1958, **30**, Feb., 273–275). The difficulty of the crucible blank in methods involving exposure to the atmosphere is considered. High vacuum equipment is superior, but careful work on the ordinary methods is reported.

Studies on the Sulphur Content of Porcelain Vessels for Rapid Analysis of Sulphur and Effectiveness of Prefiring. T. Tokuda. (*Tetsu-to-Hagane*, 1957, **43**, Sept., 891–892).

New Method of Iron Analysis. N. G. Girshovich and L. S. Dlugach. (*Lit. Proizv.*, 1957, (12), 22–23). From the experimental investigation reported in this article it is possible to conclude that the new method of investigation of iron by determining the ionic diffusion coefficient from the rate of anodic oxidation, is of great interest and may explain a number of phenomena.—L. H.

The Determination of Aluminium, Nickel, Cobalt, Copper and Iron in Alnico. D. H. Wilkins and L. E. Hibbs. (*Anal. Chim. Acta*, 1958, **18**, Apr., 372–375). An ion-exchange separation process is described.

Tris-(o-Hydroxyphenyl)-phosphine Oxide as a Colorimetric Reagent for the Determination of Ferric Iron. M. J. Holdoway and J. L. Willans. (*Anal. Chim. Acta*, 1958, **18**, Apr., 376–380). A violet-red coloration is formed in HNO_3 solution. Only Ce^{++++} interferes.

Spectrographic Analysis of Some Minor Constituents in Refractories. D. D. Innes. (*Trans. Brit. Ceram. Soc.*, 1958, **57**, Jan., 29–37). Fe_2O_3, TiO_2, CaO, MgO, ZrO_2, K_2O and Na_2O are determined, using $SrCl_2$ as buffer and an internal standard.

Spectrophotometric Determination of Nickel in Bright Cadmium and Bright Gold Plating Solutions. N. F. Doherty. (*Plating*, 1957, **44**, Sept., 971–974).

X-Ray Spectrum Method of Analysing the Diffusion of Electrons by Position, in Metals and Alloys. N. D. Borisov, V. V. Nemoshkalenko and A. M. Fefer. (*Izvest. Akad. Nauk*, 1957, (10), 1424–1434). The investigations are based on the Kβ 5 lines of electrolytic chromium and ion, and depend on the migration of ions from the conductivity zone to the K-level, and on the Kβ lines of the same elements depending on the migration of ions from the 3_p-level to the K-level in conjunction with the long wave satellite Kβ. The spectral lines were obtained at 1000° from the pure metals Chromium and Iron and from the Fe-Cr alloys containing 4; 5·8; 8; 20; 30; 45; 50 and 75% by weight of chromium.

X-Ray Spectrographic Determination of Chemical Composition within the Microvolume of Alloys. I. B. Borovskii, N. P. Il'in, L. E. Loseva, I. D. Marchukova and A. N. Deev. (*Izvest. Akad. Nauk Seriya Fiz.*, 1957, (10), 1415–1423). This new method originally developed in France in 1951 has been adapted in Russia and used for the analysis of the homogeneity of the phase composition, for welded and soldered joints and for diffusion layers.

The results obtained justify the conclusion that X-ray spectrography will have wider applications in Soviet Industry.—L. H.

Determination of Uranium Dioxide in Stainless Steel. L. Silverman, W. W. Houk and L. Moudy. (*Anal. Chem.*, 1957, **29**, Dec., 1762–1764). An X-ray fluorescence spectrographic method is described.

The Uses of Radioactive Isotopes in the Foundry. Z. Durmala. (*Prz. Odlew.*, 1957, 7, Aug., 231–238). [In Polish]. Examples of the application of radioactive isotopes for checking different processes such as: melting and casting of pure metal and alloy; investigation of the mechanism of formation of impurities, and for other processes are given. Inspection of the quality of castings by radiographic methods is discussed.

Autoradiographic Method of Investigating Metals and Alloys Using Radioactive Isotopes. M. A. Studnits and O. T. Malyukov. (*Metallov. Obra. Met.*, 1955, (6), 15–21). The process consists in covering the specimens containing isotopes, specially introduced into the material, with a sensitive emulsion. After a sufficient exposure images are registered according to the density of the isotope distribution.

The full technique of the experiments and much data obtained are given in detail.

Investigation of the Segregation of Copper in Steel By Means of Radioactive Isotopes. I. R. Kryanin, S. I. Smolenskii, M. A. Studnits and G. I. Babushkina. (*Metallov. Obra. Met.*, 1956, (3), 20–23). The autoradiographic method of determining zonal radioactivity in an ingot was used. The ^{64}Cu isotope with a half-life of 12 h was employed. It was found that there was much less segregation of Cu in a MnSi steel than in C steel, the Cu being uniformly distributed in the crystal.—R. S.

INDUSTRIAL USES AND APPLICATIONS

Metallurgy of Materials for Haulage and Cage Suspension Gear. R. Jeffrey and B. J. Nield. (*Proc. S. Wales Inst. Eng., preprint*, 1958, Mar. 20, pp. 16). Heat treatments and the effect of alloying elements, effects in service, and qualities and properties of wrought iron, mild and high tensile steels are given.

Metallurgy. H. A. Holden. (*Chem. Proc. Eng.*, 1958, **39**, Mar., 82–85). A review from the chemical engineering standpoint. (65 references).

Mechanical Springs–Materials, Finishes and Embrittlement. L. F. Spencer. (*Met. Fin.*, 1958, **56**, Feb., 66–69). Hydrogen embrittlement is reviewed and the effects of various atmospheres during heat treatment is considered.

The Properties of Cast Iron Pipes for Mining Shafts. M. Dubowicki and J. Pakulski. (*Prz. Odlew.*, 1957, **7**, June, 157–161). [In Polish]. The properties required for pipes are discussed and a comparison of steel and cast iron tubes is given. The characteristic of cast iron used for tubing in East Germany and Russia is described. The technology, mechanical properties and structure of Polish-made pipes are given and also the most frequent casting defects are discussed.

The Atomic Age Challenge to Steel. E. A. Livingstone. (*J. Met.*, 1958, **10**, Feb., 111–113). Demands upon reactor materials are briefly reviewed.

Metallurgical Research in Nuclear Power Production. J. G. Ball. (*J. Brit. Nuclear Energy Conf.*, 1958, **3**, Jan., 1–14). Constructional steels are included in a general survey.

Building a Test Reactor. (*Met. Treatment.*, 1958, **25**, Feb., 69–72). The reactor at Idaho Falls, U.S.A., is briefly described. The metallurgical aspects are noted, and austenitic stainless and other steel components are considered. The forging of the grid plates is described.

HISTORICAL

Scottish Iron. The Story of the Carron Company. W. Brown. (*Edgar Allen News*, 1958, **37**, Mar., 61–63; Apr., 88–91).

From the History of the Iron Industry in Slask Cieszynski. A. Waszek. (*Prz. Techn.*, 1956, **77**, April, 159–162). [In Polish]. The author discusses the different types of iron ore found in Slask Cieszynski, methods for its mining and the history of different concerns, especially USTON, which now has the biggest and most universal mechanical forge which is used mainly for the car industry.

Old Montreal Rails. D. H. Rooke. (*Edgar Allen News*, 1958, **37**, Apr., 84–85). An analysis and metallographic study of an old tram rail is reported.

BOOK NOTICES

BRITISH STEEL FOUNDERS' ASSOCIATION. "*Casting in Steel.*" 9 × 6¼ in., pp. [iii] + 112. Illustrated. London, 1958: Sir Isaac Pitman & Sons, Ltd. (Price 18s.).

A simple book written in simple and lucid terms—a book compiled in such a way that it is interesting as well as informative. It is to quote the preface "a revision and amalgamation into one volume of the various bulletins of the B.S.F.A. which were originally intended to assist both producer and user by promoting customer founder co-operation . . ."

Anyone who has been responsible in whatever capacity for making steel castings, will not gain a great deal from it. On the other hand, a beginner or an interested reader with no previous conception or knowledge of steel castings will gain considerably. After reading it, he will have a very clear picture of what casting in steel entails. He will become conscious of, though perhaps not particularly familiar with, the basic principles and processes involved.

This is apparently the purpose of the book. It contains sixteen chapters and a glossary of Steel Foundry Terms in only 108 pages. In such a space a reader cannot expect anything more than an introduction to the subject.—H. T. Protheroe.

Church, A. H. "*Mechanical Vibrations.*" 9½ × 6 in., pp. xii + 275. Illustrated. New York, London, 1957: John Wiley & Sons, Inc.; Chapman & Hall Ltd. (Price 54*s.*).

This book is based on courses given at New York University where the author is Professor of Mechanical Engineering. Its stated purpose is to give the principles of vibration analysis that may be used to solve the usual problems that arise and to lay the foundation for more advanced work. With such a fundamental purpose it is only to be expected that the area covered is severely restricted, but the topics which are included are dealt with very thoroughly and references are given to works on more advanced aspects. Indeed the book achieves its purpose very well.

The subject is opened in the usual manner for a work of this nature by a consideration of the free vibration of a system having a single degree of freedom first without, then with, damping. This is followed by a chapter on the forced vibration of a single degree of freedom and the problems of damping out and isolating such vibrations. Next comes a treatment of the undamped system with two degrees of freedom which is followed by detailed and practical analyses of multimass torsional and transverse systems together with useful examples of frequency calculations. A chapter is devoted to the balancing of rotating and reciprocating machines and finally a brief account is given of electrical analogies to mechanical systems. The book contains a large number of example problems.

The author is to be commended for his excellent presentation.—N. C. Lambourne.

Hartley, E. N. "*Ironworks on the Saugus. The Lynn and Braintree Ventures of the Company of Undertakers of the Ironworks in New England.* 9½ × 6½ in., pp. xvi + 328. Illustrated. Norman, 1957: University of Oklahoma Press. (Price $4.50).

Professor Hartley's valuable and well illustrated book deals with a most interesting period of the early American history—the erection of ironworks in New England which laid the foundations of the American iron and steel industry. The most important of these works were at Hammersmith on the banks of the Saugus river near Lynn and at Braintree, both in Massachusetts. The blast furnace at Braintree, erected in 1644, was the first which produced cast iron within the limits of what is now the United States. The works at Hammersmith, built in 1646–47, was the larger of the two since, in addition to the blast furnace for the production of cast or pig iron and the forge in which this was converted into wrought or bar iron, it was equipped with a slitting mill. In it, the bar iron was passed through rollers for flattening and subsequently through a set of cutters for slitting into rods which were sold to smiths mainly for the making of nails. The slitting mill at Hammersmith was the first of its kind in the New World. Moreover, it was erected at a time when such mills were still rare in the older ironworking centres, in the British Isles and on the Continent of Europe. A technical innovation at Hammersmith was the use of gabbro, a basic igneous rock found on the peninsula of Nahant. It served as a fluxing agent instead of the limestone in common use in the blast furnaces of the period.

Professor Hartley has furnished an interesting and very detailed description of work and life at Hammersmith. Some of the members of the Company of Undertakers which supplied the capital from England and owned the works were prominent English ironmasters such as Lionel Copley and Thomas Foley. Another shareholder, John Becx, of Dutch origin, owned ironworks in the Forest of Dean and in Ireland. The information concerning the activity of John Winthrop the Younger, the promoter of the enterprise and designated as "America's First Scientist," is of general interest.

Against all hopes, Braintree as well as Hammersmith were short-lived and turned out to be financial failures. Braintree furnace probably operated not much beyond 1647. At Hammersmith, production had ceased when the Company's assets were sequestrated in 1653, although there seems to have been a short revival in the 1660's. The employees moved to other works which, though mostly small and of the bloomery type, may rightly be called successor plants. In a final chapter Professor Hartley delineates the activities of the former employees of Hammersmith and their descendants and successors, the most important of whom were the Leonards, originally a French family of forge masters who emigrated to England. They preserved the legacy of the first industrial pioneers at Hammersmith and Braintree—their daring, their endurance, and their skill. In recognition of the importance of Hammersmith as the prototype of American industry a replica of the works has been erected on the original foundations. The book contains some good illustrations of this modern restoration. It lacks a map, however, which should be added to any later edition.—H. R. Schubert.

Jakob, Max. "*Heat Transfer.*" Volume II. With the technical and editorial assistance of Stothe Peter Kezios. 9½ × 6½ in., pp. xxxii + 652. Illustrated. New York; London, 1957: John Wiley & Son, Inc.; Chapman & Hall, Limited. (Price 120*s.*).

This companion volume to Jakob's previous book (1949) with the same title is subdivided into three main sections:

Part F, consisting of a study of heat radiation in spaces of simple configuration, is essentially the completion of Vol. I, and could well have been included therein. An attractive feature of this section is a discussion of the theory and relevant literature on pulverised fuel flames.

Part H, includes supplements to Vol. I in the form of new information and methods that have become available in the six years since its publication.

Part G, entitled "Selected Fields of Application," gives applications of the fundamental theory and concepts of Vol. I, and section F and H of the present volume. The topics selected include heat transfer in thermometry, recuperators, regenerators, liquid metals and packed columns. Two chapters are devoted to the theories of heat transfer in laminar and turbulent boundary layers. The section is completed by a discussion of cooling problems: in cooling towers, by falling liquid films, and the cooling of surfaces exposed to hot gases.

Taken together with its companion volume it represents the most complete appreciation of heat transfer available at the present time. Its many attractive features include the critical evaluation of existing theories, the presentation of alternative theories whenever possible, and the discussion of all theories in the light of available experimental data. Due to the completeness of the mathematical treatment of all problems it will make an ideal research and teaching tool.

One of the principal factors in favour of this book is that it collects together the results of many researches which previously were only to be found in the original literature. For the new worker in this field this will save considerable time, and the present worker will find it an invaluable reference source.

If one can level any real criticism at this work it is that, due to the completeness of its mathematical treatment, it may be rather unreadable for those with little mathematical background. On the other hand, this is probably the most attractive feature for the experienced research worker in the field.—R. G. Siddall.

Taylor, Geoffrey Ingram. "*The Scientific Papers of Sir Geoffrey Ingram Taylor.*" Volume I. Mechanics of Solids. Edited by G. K. Batchelor, F.R.S. 10½ × 7 in., pp. x + 593. Illustrated. Cambridge, 1958: Cambridge University Press. (Price 75*s.*).

This collection of papers, besides being an important work of reference, should serve as an inspiration and example to applied mathematicians, especially in the field of mechanics of materials. The thoroughness and ingenuity of the mathematics, the careful supporting experimental work carried out with the aid of various co-authors, the clarity of exposition, and the wide scope of the subject matter, all add up to an imposing body of work, unsurpassed in this field.

There are several papers on elasticity, including those on the well known soap film analogy for problems of torsion and flexure, and some work on seolotropic plates. However, most of the work is concerned with the plastic deformation of metals, the mechanics of which are treated at all levels, spanning both metal physics and macroscopic (engineering) plasticity.

Work on metal physics includes the first thorough analysis of strain in deformed single crystals, studies of hardening, and of changes of orientation due to deformation of single crystals, and the classical paper of 1934 in which it was postulated that slip occurs by the movement of dislocations. This latter paper gives the first detailed theory of strain hardening which, though no longer accepted, contains general ideas which have been retained in later theories. Following this are two papers in which was laid the basis of a theory for predicting the properties of a polycrystalline aggregate from those of a single crystal.

Work on macroscopic plasticity includes several experiments to determine the latent energy remaining in metals due to cold work, and both theoretical and experimental investigations of the fundamental macroscopic laws of plastic deformation, as well as two solutions to particular problems. There are also several important papers on the plastic behaviour of materials under high rates of loading, some of which were written during the last war and are published here for the first time.

The pleasure in reading these papers lies to a large extent in the way they reveal a most lively and competent method of work, joining theory with experiment in a manner which few mathematicians achieve so well.—Allan Green.

NEW PUBLICATIONS

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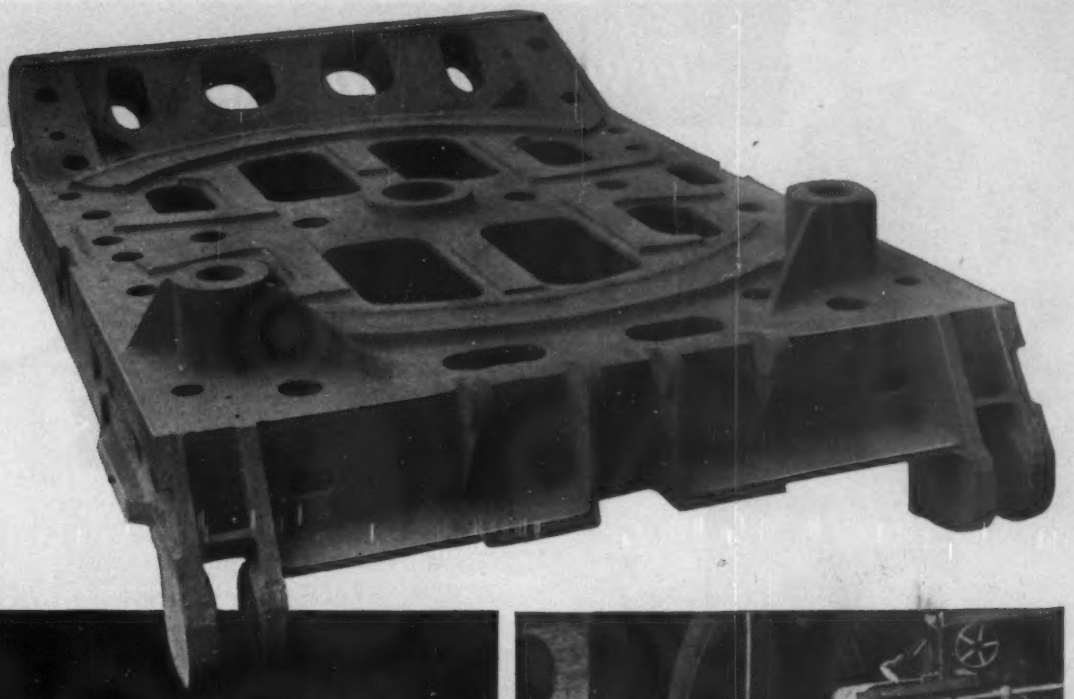

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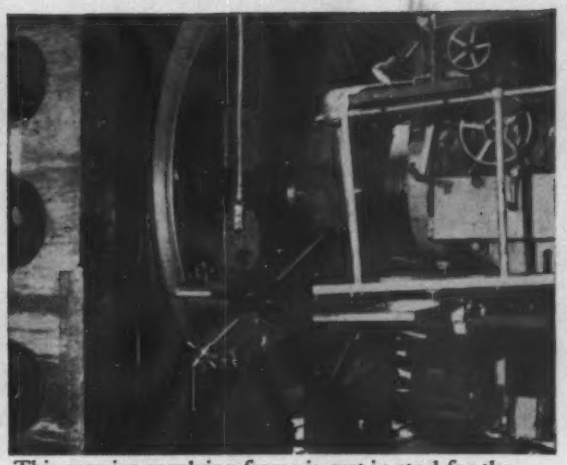

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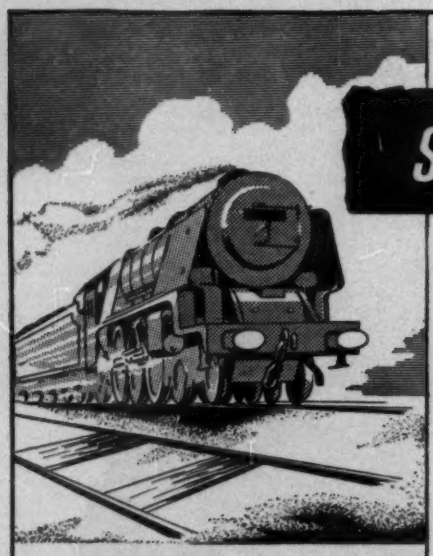

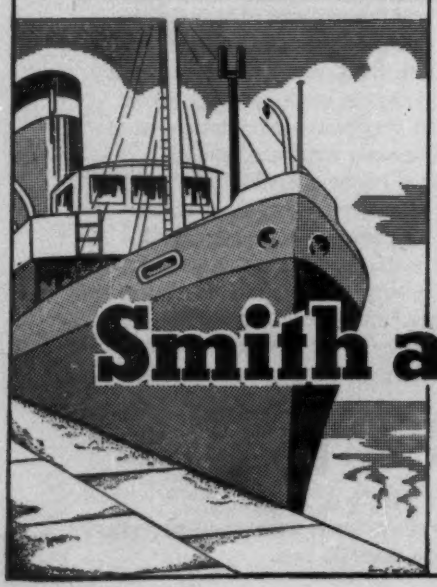

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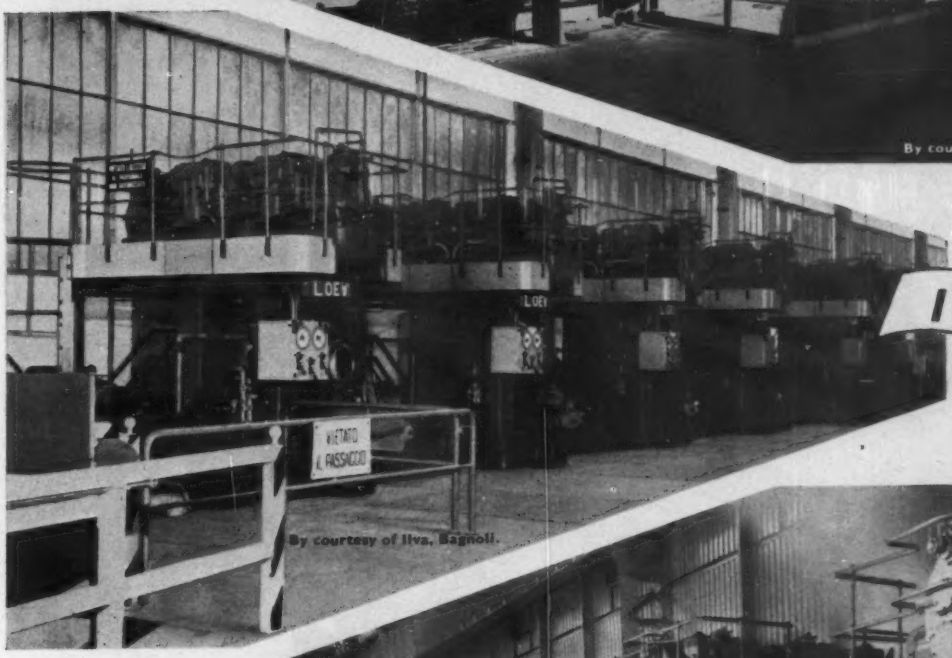

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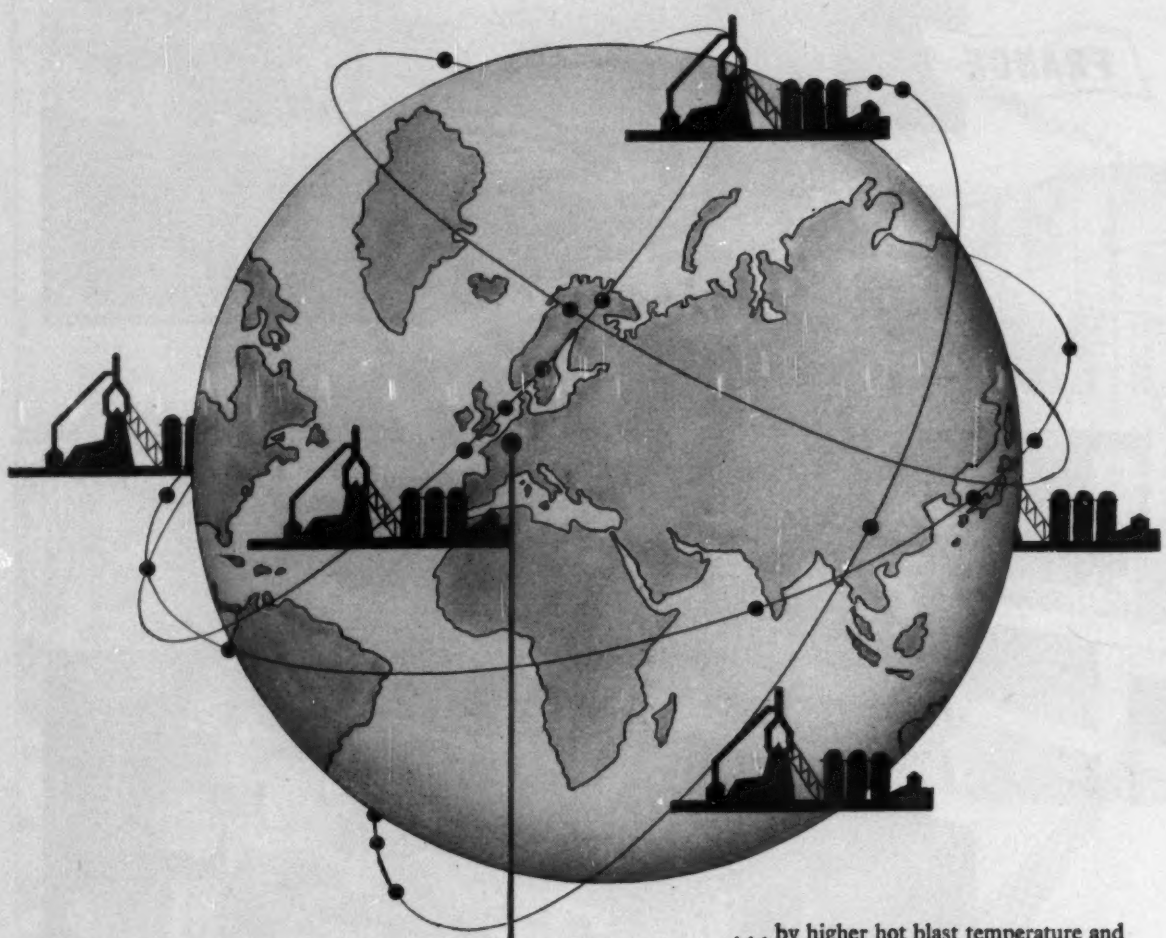

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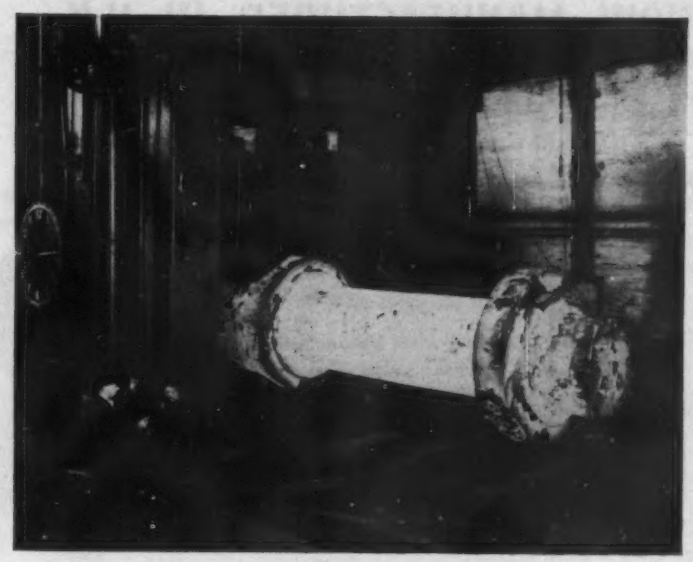

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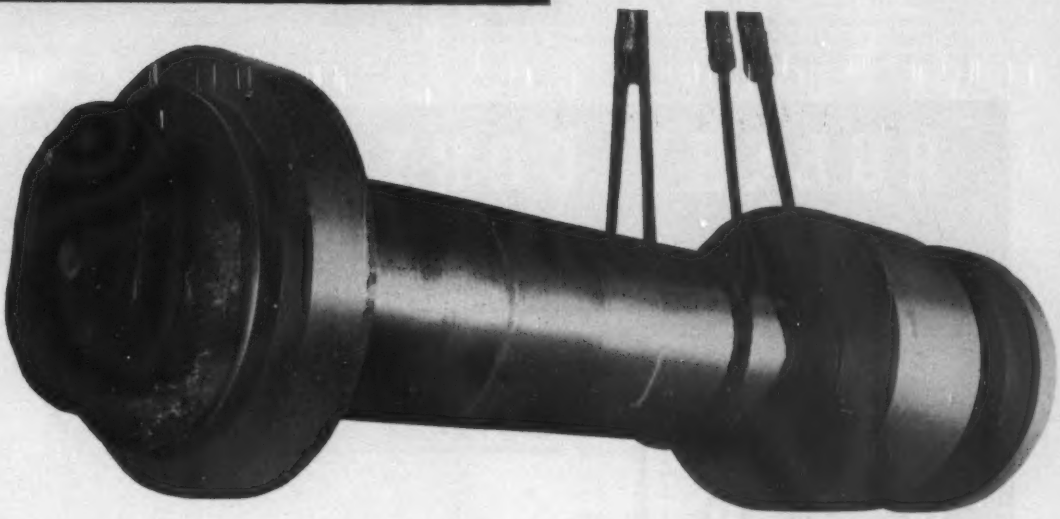

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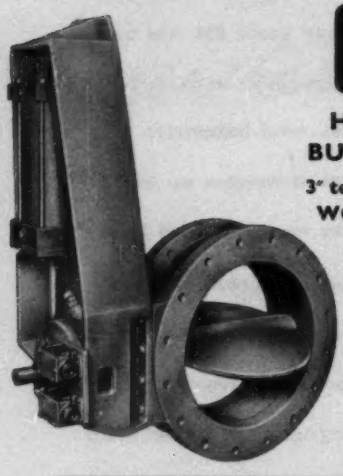

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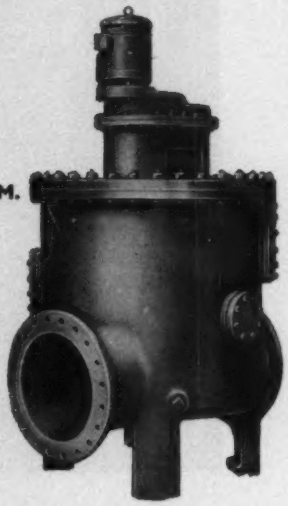

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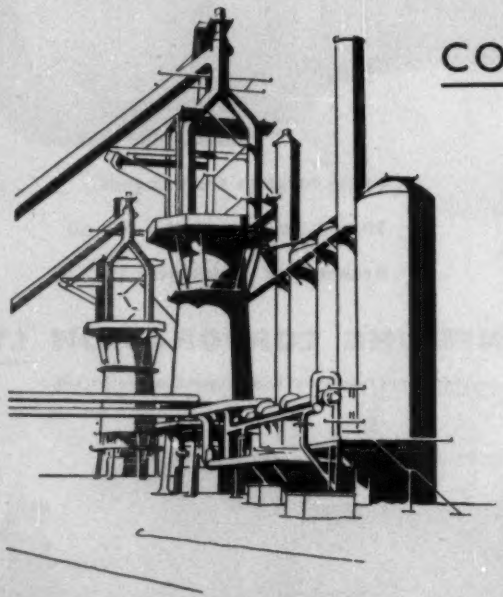

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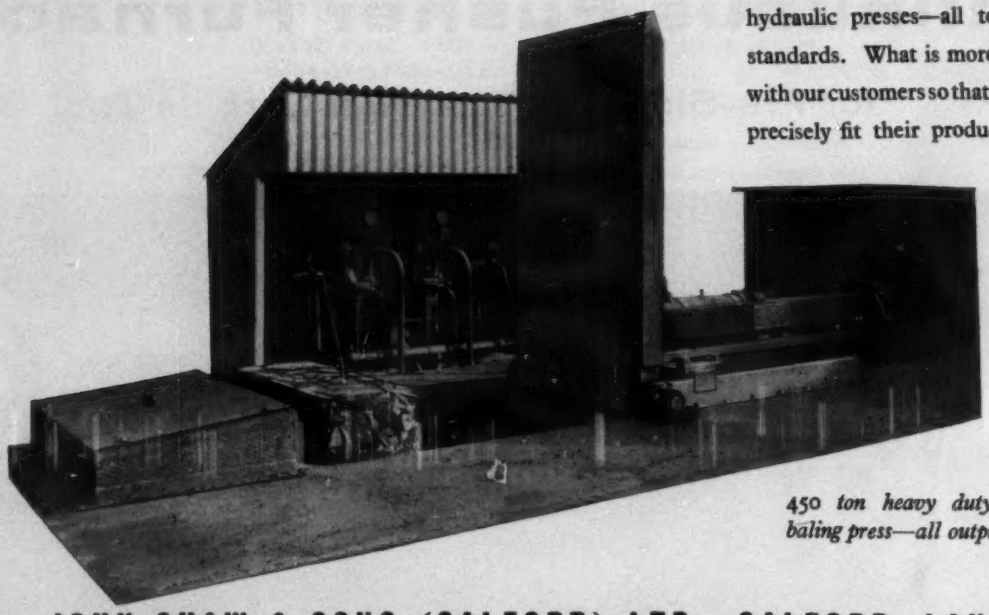

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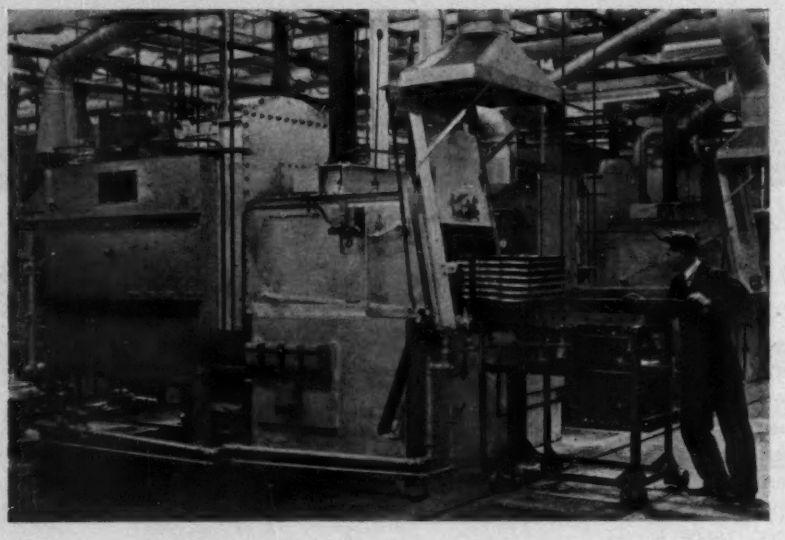

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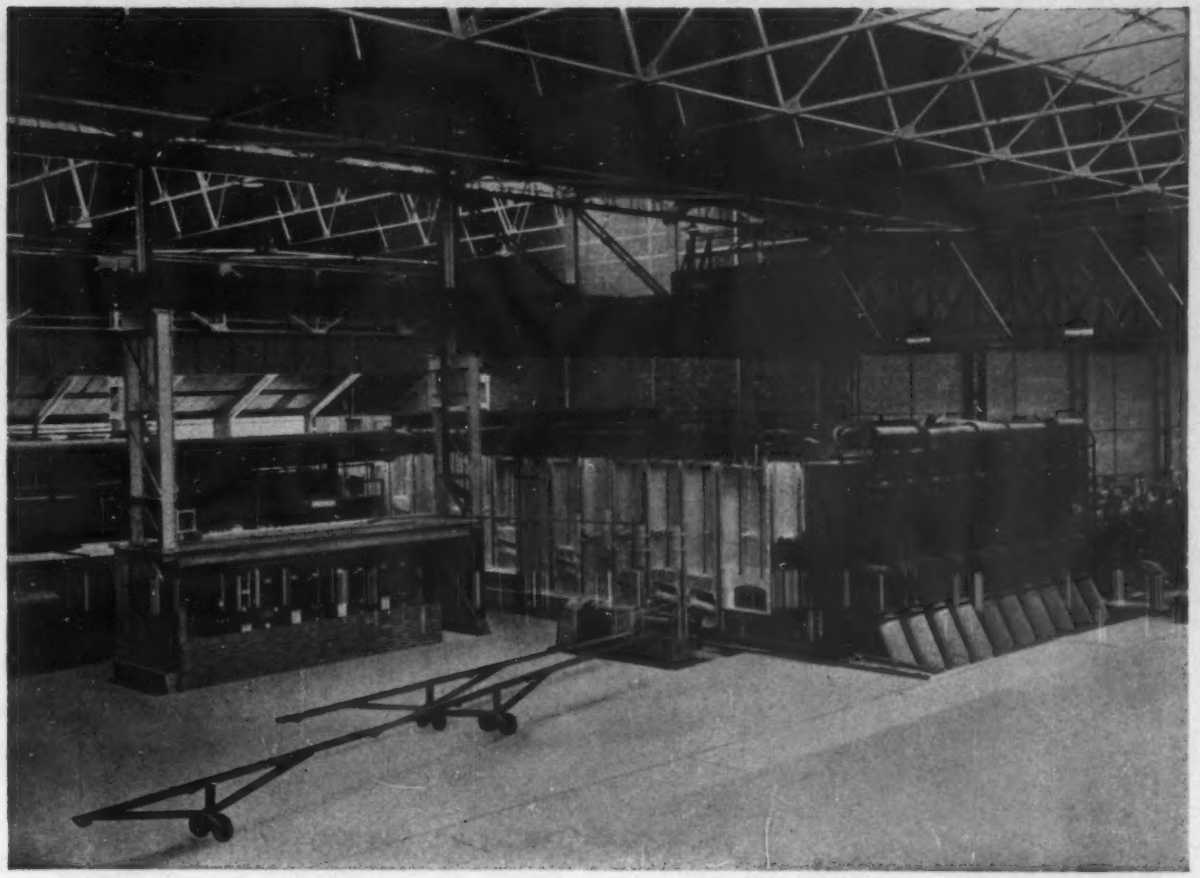

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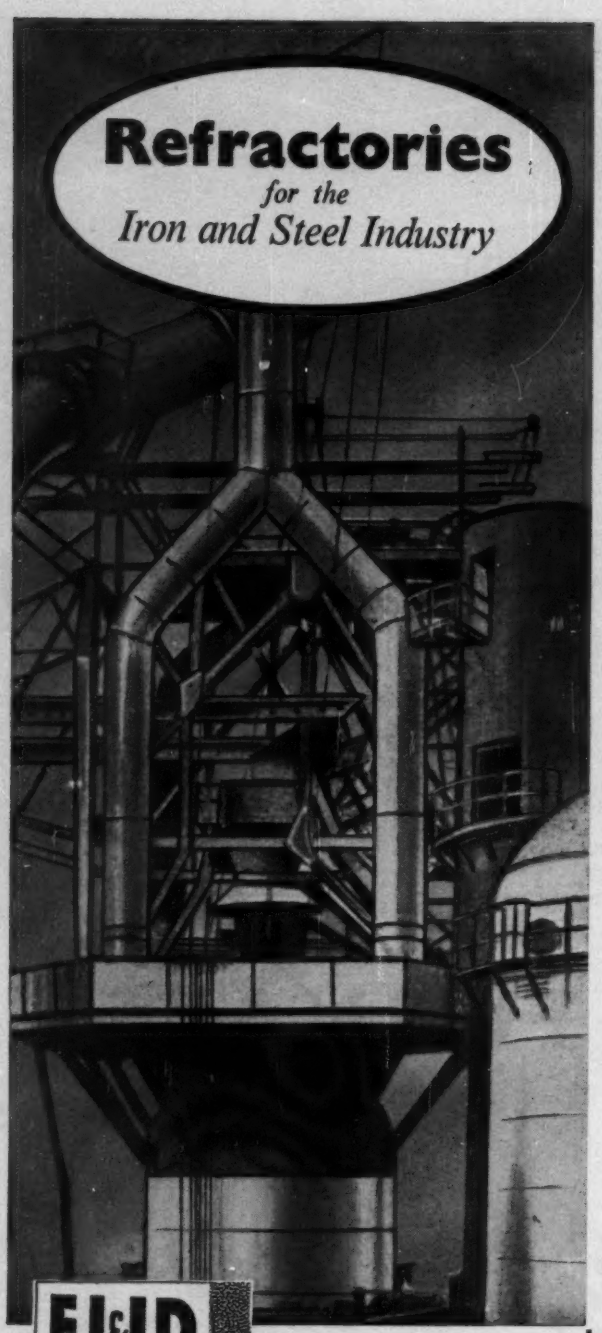

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Special Report No. 60

Proceedings of the

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In October, 1954, The Iron and Steel Institute held a Joint Meeting with the National Forgemasters' Association and La Chambre Syndicale de la Grosse Forge Française. Technical Sessions were held in London at which nine papers on forging theory and practice and forging plant were presented and discussed. The remainder of the Meeting comprised visits to the English Steel Corporation Ltd., Thos. Firth and John Brown Ltd., and Hadfield Ltd., in Sheffield.

The Proceedings at the Technical Sessions have been published as a Special Report. The five French papers and discussion are presented in English, but summaries of all the papers are also given in French. The Report, No. 60 in the Special Report series of the Institute, can be obtained from the Offices of the Institute, 4 Grosvenor Gardens, London, S.W.1, price 37*s.* 6*d.* (Members 25*s.*).

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